











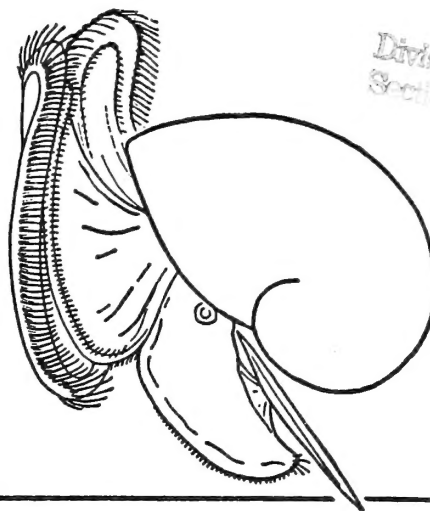




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# THE VELIGER

A Quarterly published by  
CALIFORNIA MALACOOLOGICAL SOCIETY, INC.  
Berkeley, California



## Volume 9

July 1, 1966 to April 1, 1967





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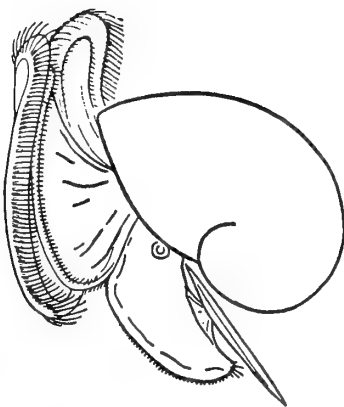
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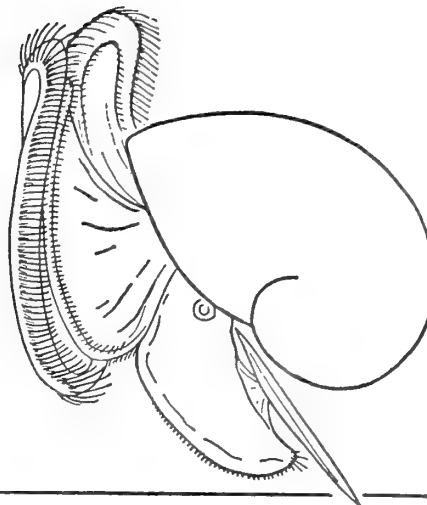
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

**ORDER**, Suborder, **DIVISION**, Subdivision, **SECTION**,  
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).  
*New Taxa*

West American Mollusk Types  
at the British Museum (Natural History)  
III. ALCIDE D'ORBIGNY's South American Collection

BY

A. MYRA KEEN

Department of Geology, Stanford University, California

(Plate 1)

ALCIDE DESSALINES D'ORBIGNY was born September 6th, 1802, at Couëron, France, near Nantes, in the north-western part of the country and thus not far from the seacoast of the Bay of Biscay. He was son of a physician of broad interests who had begun the study of marine life, especially Foraminifera. When the father's eyesight began to fail, Alcide assisted him at the microscope and thus early developed his talents for observation and drawing. He continued an interest in natural history during school training at La Rochelle. By the time he was 23, Alcide had constructed a set of models of Foraminifera (carved from wood and reproduced in plaster) and had published a classification of the group in tabular form. Soon after this he was appointed as travelling naturalist to the Muséum d'Histoire Naturelle de Paris. His first assignment was a zoological expedition to South America. He left France in 1826 and did not return until 1833, by which time he had explored parts of Brazil, Uruguay, Patagonia, Chile, Bolivia, and Peru. On the West Coast, in 1833, he collected at Callao and Islay, Peru, and at Arica, Cobija (then in Bolivia), and Valparaiso, Chile.

Back in France he devoted himself to the preparation of several large reports on his work in ethnology and zoology — not only on the "Voyage dans l'Amérique Méridionale . . ." but also on the mollusks of the West Indies and invertebrates from the Canary Islands. Completing these large works on the Recent faunas, he turned to work in paleontology for the rest of his life and published a number of monumental reports in this field also. When a Chair in Paleontology was established at the Muséum in 1853, he was elected as its first incumbent. Busy with this new responsibility, he shut himself off

from the rest of the world until his work was terminated by death in June 1857, a few months before he would have been 55 years old. The quality and the quantity of his published work give ample evidence of the great energy and ability that he had.

In the early 1850's Orbigny transferred his molluscan collections to the British Museum (Natural History), and an inventory of the South American portion was published by Gray, the curator, in 1855. Because of its historic significance, the collection has been kept intact and has been left as Orbigny mounted and labelled it, the shells being glued to heavy cardboard blocks. In a neat hand, Orbigny had lettered the names and the locality information. He also had indicated the collector if other than himself (all lots from north of Callao had been taken by a Monsieur Fontaine). The collection has not been arranged in any systematic order, although it is separated into three geographic suites — West American, Cuban, and Canary Island. There has been some disassociation of specimens and cards, what with the transfer of the material from cabinet to cabinet during the 110 years since it was sent to London. I found little difficulty in reassembling the lots when I had occasion to examine this material. In 1964, when I was at the Museum for some months, I put aside what seemed to be all the lots that Orbigny had credited to himself as author and made record photographs of most of them. Reviewing my work later, at home, I realized that I had stopped a little short of completeness. At the Museum again in 1965 for a few days, I searched out several lots I had overlooked, but a crowded schedule prevented the page-by-page review of Orbigny's published work and direct comparison of this with the collection itself. Thus, I now find that there

were a few items for which I did not search. However, I did succeed in spotting most of the types.

Among the material in the so-called Cuban collection (actually from several islands of the West Indies), I noted and photographed a few forms that have been identified by authors as also occurring on the West Coast of the Americas – *Vermetus corrodens*, *Trigonulina ornata* (now *Verticordia*), *Perna chemnitziana* (now *Isognomon*), and *Crenella divaricata*. These will not be reviewed in the present paper, for they were not described as “South American.”

The volume on Mollusca published by Orbigny in the “Voyage dans l’Amérique Méridionale . . .” comprised some 758 pages of text and 85 colored plates. The work was issued irregularly over a period of years, completed in 1847. Collation of the pages and plates has been difficult for bibliographers. Libraries of that day did not always mark the dates of receipt of separate parts or keep the original wrappers. Early references to the work therefore were apt to be incomplete or inaccurate. Charles Sherborn, compiler of that greatest of nomenclators, the “Index Animalium,” in 1902–1933, expressed dissatisfaction with the then-available evidence as to dates. Later, however, he had access to a set of the work in original wrappers and published a tabular collation (SHERBORN & GRIFFIN, 1934). For the present list I have adopted the revised dates. Under “References” I have quoted the evidence given by SHERBORN & GRIFFIN but have rearranged it into chronologic order. Dates on three plates still are lacking, but this affects only one name, which therefore will have to be dated as 1847 under Article 22 (c) of the International Code. Many of the date changes in the present list are caused by the validation of names in the plate explanations, which often were issued in advance of the text.

The format adopted here is to cite the species names in their original generic combination but in a modern systematic sequence rather than that followed by Orbigny. His name as describer is to be understood and is not repeated for each entry. An asterisk preceding the species name indicates a change in date from that in most lists. Then, in order, follow: date; page, plate, and figure reference; type locality; British Museum registry number (note that most of these were assigned December 4th, 1854); remarks, including notes on nomenclature; modern allocation, if different from Orbigny’s; references to a figure, either in a more modern work or in this paper. Because the “Voyage . . .” is a rare work and not available in most libraries, I have cited reproductions of his figures by later authors (notably TRYON and PILSBRY in the Manual of Conchology) and discussions in more

accessible modern works. Although I photographed most of the types, I am including in my plate mostly the forms that have not been well understood by authors.

A few minor gastropod groups (pteropods, heteropods, and nudibranchs) have been omitted in this canvass, and it does not cover Cephalopoda. Non-marine forms of course are excluded.

A comment as to the spelling of D’Orbigny’s name is in order, for authors have variously recorded it. Dall adopted the spelling Orbigny in 1909, and I have followed this precedent for two reasons: in indexes, according to the Style Manual for Biological Journals, the entry would be “Orbigny, Alcide d’”; and, for formation of scientific names from personal names, the International Code recommends dropping of the nobiliary particle *de*, so that a name dedicated to him should be spelled *orbignyi*. It is, of course, correct to use it in connection with the Christian name: “Alcide d’Orbigny,” and, in writing of him as a person, when not citing the Christian name, one presumably would use the spelling “D’Orbigny.” As species authority, he is ORBIGNY. One must admit, though, that he, on his labels and in his book, used the abbreviation “d’O.” or “d’Orb.”

## GASTROPODA

### PATELLACEA

- \* *Patella araucana*. 1839: p. 482, pl. 65, figs. 4-6. Valparaíso, Chile. B. M. no. 54.12.4.244, 11 specimens. Refigured by PILSBRY, 1891, Man. Conch., v. 13, p. 35, pl. 16, figs. 21, 22. *Acmaea*.
- Patella ceciliana*. 1841: p. 482, pl. 81, figs. 4-6. Falkland Islands. Range to Antofagasta and Valparaíso, Chile, *fide* DALL, 1909. Not searched. *Acmaea*.
- Patella parasitica*. 1841: p. 481, pl. 81, figs. 1-3. Valparaíso and Arica, Chile. B. M. no. 54.12.4.300, 302, 15 specimens. *Scurria*.
- Patella pretrei*. 1841: p. 481, pl. 78, figs. 15-17. Payta, Peru; Valparaíso and Arica, Chile. Not searched. Refigured, PILSBRY, op. cit., p. 33, pl. 34, figs. 9, 10. = *Acmaea viridula* (LAMARCK, 1819).
- Patella maxima*. 1841: p. 482 (no fig.). Payta, Peru. B. M. no. 54.12.4.437, 1 specimen. = *P. mexicana* BRODERIP & SOWERBY, 1829.
- “*Acmaea scutum* Esch.” of Orbigny, 1839 (not of RATHKE ex ESCHSCHOLTZ, MS, 1833): p. 479, pl. 64, figs. 8 to 10. Cobija and Arica, Chile. B. M. no. 54.12.4.304, 12 specimens. Refigured, PILSBRY, 1891, op. cit., p. 32, pl. 4, figs. 77, 79. The identity of the species



remains unclear. D'Orbigny had first labelled this *Lottia punctata* GRAY, a preoccupied name, then changed to *Acmaea scutum* ESCH. A new name has been provided for his misidentification: *Acmaea orbignyi* DALL, 1909.

#### FISSURELLACEA

*Fissurella fontainiana*. 1841: p. 477, pl. 78, figs. 12-14. Islay, Peru, 18 fms. B. M. no. 54.12.4.613. Very close to *Diodora alta* (C. B. ADAMS, 1852) and to *Fissurella aspera* SOWERBY, 1835 (*non* RATHKE *ex* ESCH-SCHOLTZ MS, 1833) = *Fissuridea asperior* DALL, 1909, the former from Panama, the latter from Peru. *Diodora*. (Plate 1, Figure 13).

#### TROCHACEA

*Trochus araucanus*. 1840: p. 410, pl. 55, figs. 5-8. Valparaíso, Chile. Not searched. = *Monodonta nigerrima* (Gmelin, 1791), *fide* PILSBRY, 1889, Man. Conch., v. 11, p. 97.

*Trochus luctuosus*. 1840: p. 409, pl. 76, figs. 16-19. Valparaíso, Chile, 12 fms. B. M. no. 54.12.4.390, 14 specimens. *Tegula* (*Chlorostoma*).

*Trochus microstomus*. 1840: p. 410, pl. 76, figs. 20, 21. Valparaíso, Chile. Not searched. = *Chlorostoma tridentatus* (POTIEZ & MICHAUD, 1838), *fide* PILSBRY, 1889, op. cit., p. 175.

*Littorina umbilicata*. 1840: p. 394, pl. 76, figs. 1-3. Arica and Cobija, Chile. Not searched. Refigured, STRONG, 1928, Proc. Calif. Acad. Sci., ser. 4, vol. 17, no. 6, p. 200, pl. 10, figs. 16, 17, as a phasianellid. *Tricolia*.

#### NERITACEA

*Neritina fontaineana*. 1840: p. 406, pl. 76, figs. 14, 15. Guayaquil, Ecuador. B. M. no. 54.12.4.382, 8 specimens. Refigured, TRYON, 1888, Man. Conch., vol. 10, p. 76, pl. 23, figs. 92, 93, as *N. latissima* BRODERIP, 1833, var. A later synonym is: *N. guayaquilensis* "ORB." of SOWERBY, 1849.

#### LITTORINACEA

*Littorina araucana*. 1840: p. 393, pl. 53, figs. 8-10. Chile. Not searched. Refigured, TRYON, 1887, op. cit., vol. 9, p. 250, pl. 48, figs. 95, 96.

#### TURRITELLACEA

*Turritella broderipiana*. 1840: p. 388 (no fig.). Payta, Peru. B. M. no. 54.12.4.356, 1 specimen. Type of

subgenus *Broderiptella* OLSSON, 1964. (Plate 1, Figure 21).

#### CERITHIACEA

\* *Cerithium montagnei*. 1839: p. 443, pl. 63, figs. 3, 4. Guayaquil, Ecuador, in brackish water. B. M. no. 54.12.4.504, 4 specimens. *Cerithidea*.

*Cerithium peruvianum*. 1841: p. 443, pl. 77, figs. 9, 10. Payta, Peru; Arica, Chile. B. M. no. 54.12.4.511, 6 specimens. Refigured, TRYON, 1887, op. cit. p. 153, pl. 30, fig. 21. *Bittium*. (Plate 1, Figures 12 a-b).

*Rissoina inca*. 1840: p. 395, pl. 53, figs. 11-16. Arica and Cobija, Chile. "Cobija, Bolivia," on original label. B. M. no. 54.12.4.367, 13 specimens. Type of genus *Rissoina*. (Plate 1, Figures 6 a-c).

#### NATICACEA

*Natica cora*. 1840: p. 401, pl. 76, figs. 10, 11. Callao, Peru. B. M. no. 54.12.4.375, 7 specimens. *Polinices*. (Plate 1, Figures 10 a-c).

#### HIPPONICACEA

*Pileopsis ungaricoides*. 1841: p. 457, pl. 78, fig. 4. Payta, Peru. B. M. no. 54.12.4.554, 1 broken specimen. Refigured, TRYON, 1886, op. cit., vol. 8, p. 131, pl. 40, figs. 82, 83. *Capulus*. (Plate 1, Figures 14 a-b).

#### CALYPTRAEACEA

\* *Calyptraea intermedia*. 1839: p. 463, pl. 59, figs. 4-6. Islay, Peru, 20 fms. B. M. no. 54.12.4.566, 3 specimens. Refigured, TRYON, 1886, op. cit., vol. 8, p. 122, pl. 35, figs. 89, 90. (Plate 1, Figures 11 a-b).

#### CYMATIACEA

*Ranella kingii*. 1841: p. 451 (no fig.). Mocha, Chile, 10 fms. B. M. no. 54.12.4.533, 3 specimens. *Pro Triton ranelliformis* KING & BRODERIP, 1832, which also was renamed *Ranella vexillum* SOWERBY, Oct. 1841. *Argobuccinum*.

#### MURICACEA

*Murex monoceros*. 1841: p. 454, pl. 78, figs. 1, 2 [*non* SOWERBY, 1841]. Payta, Peru. B. M. no. 54.12.4.547, 2 specimens. Refigured and renamed, TRYON, 1880, op. cit., vol. 2, p. 126, pl. 35, figs. 384, 385, as *Murex fontainei* TRYON, 1880. *Ceratostoma*. Very close to *C. lugubris* (BRODERIP, 1833), which was erroneously placed in synonymy in "Sea Shells of Tropical West America" as an *Ocenebra*. The

varices are heavier than in *C. lugubris*, of which it may prove to be a variant. There is a small tooth on the outer lip. (Plate 1, Figures 18 a-b).

*Purpura delessertiana*. 1841: p. 439, pl. 77, fig. 7. Payta, Peru. B. M. no. 54.12.4.493. Refigured, TRYON, 1880, op. cit., vol. 2, p. 169, pl. 50, fig. 95. *Thais* (*Stramonita*). (Plate 1, Figure 15).

#### BUCCINACEA

*Columbella sordida*. 1841: p. 430, pl. 77, figs. 2-4. Callao, Peru; Arica, Chile. B. M. no. 54.12.4.450, more than 12 specimens. Refigured, TRYON, 1883, op. cit., vol. 5, p. 117, pl. 47, fig. 42. = *Mitrella unicolor* (SOWERBY, 1832).

\* *Fusus fontainei*. 1839: p. 447, pl. 63, fig. 2. Callao, Peru; Cobija, Chile. B. M. no. 54.12.4.517, 5 specimens. Refigured, TRYON, 1881, op. cit., vol. 3, p. 137, pl. 56, fig. 379. Synonym: *Fusus alternatus* PHILIPPI, 1847, usually cited as the prior or preferred name. *Austrofuscus*.

\* *Fusus purpuroides*. 1839: p. 448, pl. 65, fig. 1. Callao and Payta, Peru, 6 fms. B. M. no. 54.12.4.501, 5 specimens. Refigured, TRYON, 1881, op. cit., vol. 3, p. 149, pl. 42, fig. 217. = *Cantharus* (*Solenosteira*) *fusiformis* (BLAINVILLE, 1832).

*Murex inca*. 1841: p. 455, pl. 78, fig. 3. Callao, Peru, 6 fms. B. M. no. 54.12.4.548, 5 specimens. Refigured, TRYON, 1881, op. cit., vol. 3, p. 164, pl. 74, fig. 301. *Cantharus*, s. l. (Plate 1, Figures 9 a-b).

*Nassa fontainei*. 1841: p. 433, pl. 77, figs. 5, 6. Payta, Peru. B. M. no. 54.12.4.456-457, 2 specimens. Refigured, but poorly, TRYON, 1882, op. cit., vol. 4, p. 32, pl. 10, fig. 102, as a synonym of *N. exilis*, from which the lectotype (here selected) differs by being proportionately wider, the axial ribs with beads at the suture. *Nassarius*. No. 456 is ORBIGNY's figured specimen and is here selected as lectotype; no. 457, although mounted and labelled by Orbigny as this species, seems to be closer to *N. versicolor* (C. B. ADAMS, 1852). (Plate 1, Figure 3).

#### VOLUTACEA

*Mitra inca*. 1841: p. 427, pl. 77, fig. 1. Payta, Peru. B. M. no. 54.12.4.434, 1 specimen. Refigured, TRYON, 1882, op. cit., vol. 4, pl. 39, fig. 140. *Mitra* (?*Scabricola*). (Plate 1, Figure 17).

#### OPISTHOBRANCHIATA

#### ANASPIDEA

*Bulla peruviana*. 1837: p. 211, pl. 19, figs. 4, 5. Peru. Not searched. Refigured, PILSBRY, 1895, op. cit., vol. 15, pl. 43, figs. 3-5. *Haminoea*.

*Tornatella venusta*. 1840: p. 399, pl. 56, figs. 4-6. Payta, Peru. Not searched. Refigured, PILSBRY, 1893, op. cit., vol. 15, p. 164, pl. 18, figs. 100, 101. *Acteon* (*Rictaxis*), near *A. casta* (HINDS, 1844) but with a lower spire and more coloration.

### Explanation of Plate 1

All specimens in the Type Collection, Mollusca Section, British Museum (Natural History)

Figure 1: *Lima pacifica* ORBIGNY. Holotype of *Lima arcuata* SOWERBY. x 0.8.

Figure 2: *Mytilus "falcatus"* ORBIGNY = *M. strigatus* HANLEY. Syntype, from Brazil. x 0.5.

Figure 3: *Nassa fontainei* ORBIGNY. Lectotype. x 1.5.

Figure 4, a-c: *Auricula globulus* ORBIGNY. 3 syntypes. x 2.

Figure 5, a-b: *Mytilus soleniformis* ORBIGNY. 2 syntypes. x 0.8.

Figure 6, a-c: *Rissoina inca* ORBIGNY. 3 syntypes. x 1.7.

Figure 7, a-b: *Pectunculus "minor"* ORBIGNY = *Glycymeris chemnitzii* DALL. Exterior and interior of holotype. x 0.8.

Figure 8, a-b: *Venus paytenensis* ORBIGNY. Exterior and interior of 2 syntypes of *Cytherea affinis* BRODERIP. x 0.7.

Figure 9, a-b: *Murex inca* ORBIGNY. Back and apertural views, 2 syntypes. x 1.

Figure 10, a-c: *Natica cora* ORBIGNY. 3 syntypes, back and apertural views. x 1.

Figure 11, a-b: *Calyptreaa intermedia* ORBIGNY. Interiors of 2 syntypes. x 2. (Actually, specimens are circular in

outline but appear oblique because of the necessary camera angle).

Figure 12, a-b: *Cerithium peruvianum* ORBIGNY. 2 syntypes x 5.5.

Figure 13: *Fissurella fontainiana* ORBIGNY. Holotype. x 1.3.

Figure 14, a-b: *Pileolus ungaricoides* ORBIGNY. a) above, interior, x 1.3; b) below, exterior, x 2.2.

Figure 15: *Purpura delessertiana* ORBIGNY. Syntype. x 1.

Figure 16, a-b: *Ostrea aequatorialis* ORBIGNY. 2 syntypes. a) left, exterior, b) right, interior x 0.5.

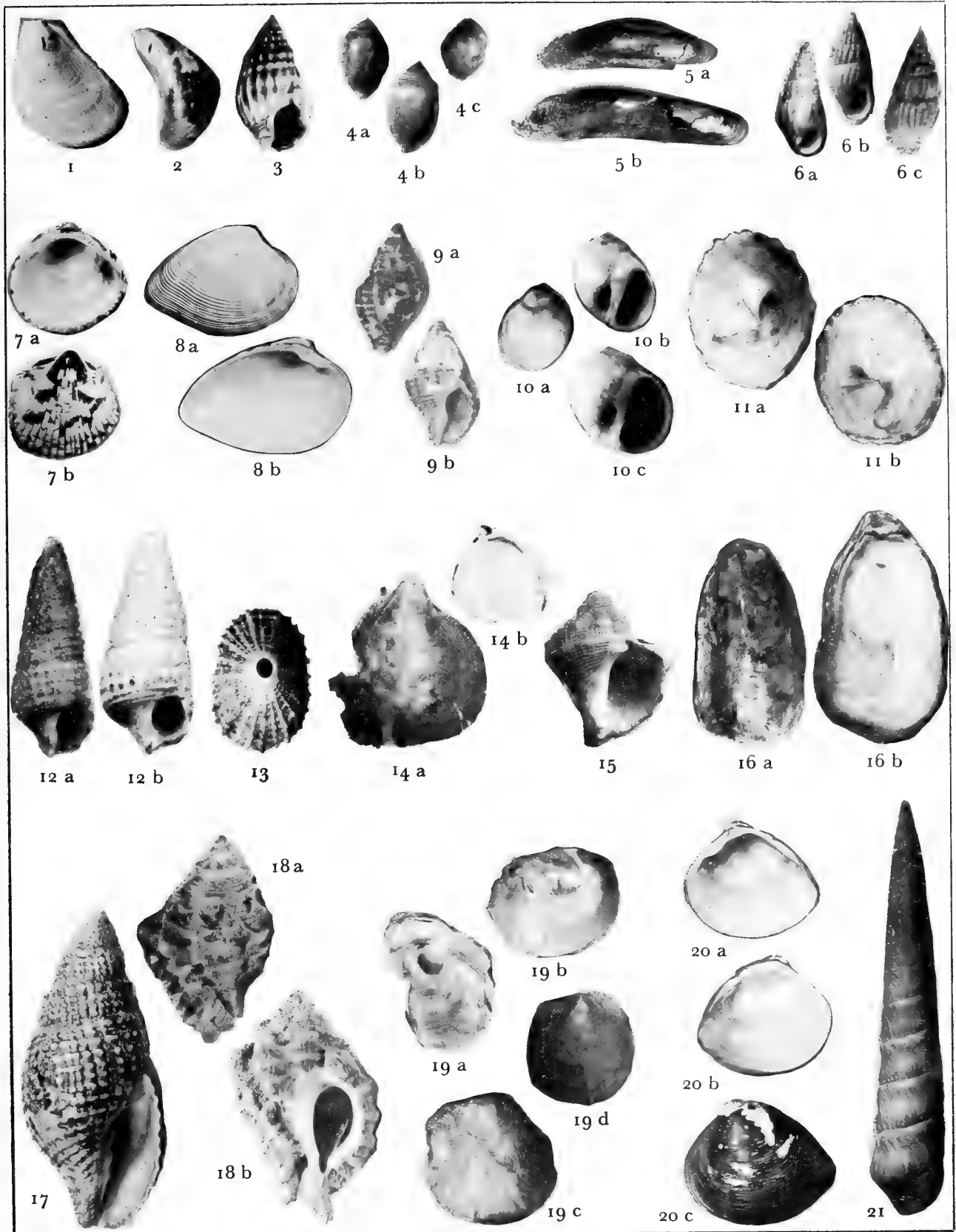
Figure 17: *Mitra inca* ORBIGNY. Holotype. x 2.

Figure 18, a-b: *Murex "monoceros"* ORBIGNY = *M. fontainei* TRYON. a) back, b) apertural views. 2 syntypes. x 1.1.

Figure 19, a-d: *Anomia peruviana* ORBIGNY. Above, 2 broken syntypes showing the perforate valve; below, 2 other syntypes showing exterior sculpture. x 0.8.

Figure 20, a-c: *Cyclas fontainei* ORBIGNY. Interior views of one syntype, exterior of another. x 0.5.

Figure 21: *Turritella broderipiana* ORBIGNY. Holotype. x 0.4.





## PYRAMIDELLACEA

- Chemnitzia cora*. 1840: p. 398, pl. 76, figs. 7-9. Payta, Peru. Not searched. *Turbonilla*.

## CEPHALASPIDEA

- \* *Aplysia inca*. 1836: p. 207, pl. 19, figs. 1-3. Callao, Peru. Not searched. Refigured, PILSBRY, 1895, op. cit., vol. 16, pl. 19, figs. 29-31.
- \* *Aplysia nigra*. 1836: p. 209, pl. 18, figs. 1, 2. Callao, Peru. Not searched. Refigured, PILSBRY, loc. cit., pl. 22, figs. 10, 11.
- \* *Aplysia rangiana*. 1835: p. 210, pl. 17, figs. 11-13. Payta, Peru. Not searched. Refigured, PILSBRY, loc. cit., pl. 19, figs. 34-36.

## PULMONATA

- Auricula acuta*. 1835: (Magasin de Zool., vol. 5, p. 23); figured, 1837, p. 327, pl. 42, figs. 4, 5. Guayaquil, Ecuador. Not searched. *Marinula*.
- Auricula globulus*. 1835 (Magasin de Zool., p. 22, ex FERUSSAC, MS?); cited, 1837, p. 327, as "d'Orb.", but not figured. Guayaquil, Ecuador. B. M. no. 54.12.4.243, 3 specimens. Original label credits the name to Ferussac; one syntype figured by REEVE, 1878, Conchologia Iconica, vol. 20, *Auricula*, pl. 6, fig. 43. *Detracia*. (Plate 1, Figures 4 a-c).
- \* *Auricula reflexilabris*. 1837: p. 326, pl. 42, figs. 1-3. Lima and Callao, Peru. Not searched. *Tralia*.
- Auricula stagnalis*. 1835 (Magasin de Zool., p. 23); figured, 1837: p. 325, pl. 42, figs. 7, 8. Guayaquil, Ecuador. B. M. no. 54.12.4.240, 2 specimens. *Ellobium*.

## AMPHINEURA

- Chiton bicostatus*. 1841: p. 486, pl. 81, figs. 7-9. Peru; Arica, Chile. Not searched. = *C. pulchellus* GRAY, 1828. *Callistochiton*, fide DALL, 1909.
- \* *Chiton inca*. 1839: p. 486, pl. 65, figs. 20-24. Islay, Peru. Refigured, PILSBRY, 1894, op. cit., vol. 14, pl. 27, figs. 52-54, as *Ischnochiton*.

## PELECYPODA

## NUCULACEA

- \* *Leda sowerbyana*. 1845: p. 544 (no fig.). Xipixapi, Ecuador. New name for *Nucula lanceolata* "LAMARCK, 1819" of G. SOWERBY, 1833 [non J. SOWERBY, 1817]. Probable holotype at B. M., registry

number not yet assigned. *Adrana*. (Species figured and discussed by OLSSON, 1961, p. 69, pl. 3, fig. 3).

- \* *Leda ornata*. 1845: p. 546, pl. 82, figs. 4-6. Payta, Peru. Not searched. *Nuculana (Saccella)*. (Species discussed by OLSSON, 1961, op. cit., p. 60, pl. 2, fig. 3).

## ARGACEA

- Arca aequatorialis*. 1846: p. 636 (no fig.). Santa Elena, Ecuador. New name for *Arca ovata* REEVE, 1844 [non GMELIN, 1791]. REEVE's type searched but not yet located at B. M.; cited as from Cuming Collection by Reeve. *Anadara (Cunearca)*. (Species figured and discussed by OLSSON, 1961, op. cit., p. 95, pl. 9, figs. 4, 5).
- Arca reeveana*. 1846: p. 635 (no fig.). Payta, Peru. B. M. no. 54.12.4.786, 2 specimens. New name for "*Arca helblingii* BRUGUIÈRE" of REEVE, 1844 [not of BRUGUIÈRE, 1789]. *Barbatia (Cucullaearca)*.
- Arca sowerbyi*. 1846: p. 637 (no fig.). Atacama, Colombia, 7 fms. Holotype searched at B. M., 1964, but not found. Unneeded innovation for *Arca biangulata* SOWERBY, 1833, non *A. biangula* LAMARCK, 1805. Species figured and discussed by OLSSON, 1961, op. cit., p. 98, pl. 8, fig. 5, as *Anadara (Caloosarca)*, a new subgenus by OLSSON, 1961.
- Pectunculus minor*. 1846: p. 628 (no fig.). Isla Plata, Ecuador. Homonym (non LEA, 1833); renamed *Glycymeris chemnitzii* DALL, 1909. Based on a figure in REEVE, Conchologia Iconica, vol. 1, *Pectunculus* pl. 6, fig. 28. Holotype, B. M. registry number not yet assigned. Considered a synonym of *Tucetona strigilata* (SOWERBY, 1835) by OLSSON, 1961, p. 108, pl. 11, fig. 3. *Glycymeris*. (Plate 1, Figures 7 a-b).

## MYTILACEA

- Mytilus americanus*. 1846: p. 648 (no fig.). Callao, Peru. Not searched. Probably a synonym of *M. (Aulacomya) ater* MOLINA, 1782.
- \* *Mytilus falcatus*. 1846: pl. 84, figs. 38, 39 (as *M. charuanus*). [Non GOLDFUSS, 1837]. Rio de Janeiro, Brazil; Maldonado, Uruguay. B. M. nos. 54.12.4.812-813, 6 or more specimens, labelled as *M. falcatus*. Allocated to *Mytella* by SOOT-RYEN, 1955, p. 50, and reported as ranging from Bahía de Petatlan, Mexico to Ecuador and the Galápagos Islands. OLSSON, 1961, however (p. 113-114) cites only *Mytilus arciformis* (DALL, 1909) and rejects *Mytella "falcata"* by implication from the West Coast fauna, citing the range of *Mytilus arciformis* (which he does not consider to be a *Mytella*) as El Salvador to Guayaquil,

Ecuador. The identity of material north of El Salvador thus remains in doubt. SOOT-RYEN had synonymized *M. arciformis* with *Mytella* "*falcata*." The name *M. charruana* (ORBIGNY, 1847), printed in the plate explanation, is available as replacement for the homonymous *M. "falcata*." However, there seems to be an earlier synonym, as Dr. L. G. Hertlein has pointed out to me – *Mytilus strigatus* HANLEY, 1843 (Illustrated and descriptive catalogue of bivalve shells, pp. 251, 388, pl. 24, fig. 34), which was described without locality from a Hinds MS and figured in 1847 with the statement that Orbigny had described the species as *M. falcatus*. Thus, it would seem that if West Coast representatives of this form do occur, they should take the name *Mytella strigata* (HANLEY, 1843). (Plate 1, Figure 2).

\* *Mytilus chenuanus*, spelling error for *M. chenui* RÉGLUZ, 1842. 1842: p. 649, pl. 85, figs. 14-16. Brazil. B. M. no. 54.12.4.810, 1 specimen. Gray's list cites the locality as Payta, Peru. The B. M. specimen closely resembles *Gregariella denticulata* (DALL, 1871). Thus, Orbigny's material may not be correctly identified. *Gregariella*.

\* *Mytilus soleniformis*. 1842: p. 649, pl. 85, figs. 17, 18. Payta, Peru. B. M. no. 54.12.4.811, 2 specimens. Type of genus *Adula*. OLSSON, 1961, p. 132, extends the range north to Panama. (Plate 1, Figures 5a, b).

*Lithodomus inca*. 1846: p. 651 (no fig.). Payta, Peru. B. M. no. 54.12.4.789, 1 specimen. Holotype figured by OLSSON, 1961: p. 135, pl. 15, fig. 1, as *Lithophaga (Labis)*. (The species was considered a synonym of *Modiola attenuata* DESHAYES, 1836 by SOOT-RYEN, 1955, p. 99).

*Lithodomus peruvianus*. 1846: p. 651 (no fig.). Callao, Peru. B. M. no. 54.12.4.788, 3 specimens. One syntype figured by OLSSON, 1961, p. 135, pl. 15, fig. 2a. *Lithophaga (Labis)*.

#### PECTINACEA

*Pecten inca*. 1846: p. 663 (no fig.). Santa Elena, Ecuador. New name for *Pecten tumidus* SOWERBY, 1835, non TURTON, 1822. = *Aequipecten circularis* (SOWERBY, 1835).

*Pecten tumbezensis*. 1846: p. 663 (no fig.). Tumbes, Peru. New name for *Pecten aspersus* SOWERBY, 1835, non LAMARCK, 1819. Type searched at B. M. in 1964 but not found. Species figured and discussed by OLSSON, 1961, p. 164, pl. 21, fig. 2. *Aequipecten (Pacipecten)*. [Type of subgenus *Pacipecten* OLSSON, 1961].

*Lima pacifica*. 1846: p. 654 (no fig.). Lord Hood's Island, Panama, Guayaquil, Guacomayo (Cuming Collection). New name for *Lima arcuata* SOWERBY, 1843, non GEINITZ, 1840 of authors, non *Ostrea arcuata* BROCCHI, 1814, a *Lima*. Sowerby's probable holotype, B. M., not yet assigned a registry number. Species figured and discussed, OLSSON, 1961, p. 170, pl. 17, fig. 1. *Lima (Promantellum)*. (Plate 1, Figure 1).

#### OSTREACEA

*Ostrea aequatorialis*. 1846: p. 672 (no fig.). Isla de la Luna, Guayaquil, Ecuador. Holotype, B. M. no. 54.12.4.823. Probably a synonym of *O. columbiensis* HANLEY, 1846. (Plate 1, figs. 16a-b).

#### ANOMIACEA

*Anomia peruviana*. 1846: p. 673 (no fig.). Payta, Peru. B. M. no. 54.12.4.824, 4 specimens; syntypes thin and somewhat broken, showing variation in color. Species figured and discussed by OLSSON, 1961, p. 177, pl. 24, fig. 2. (Plate 1, Figures 19a-d).

#### CORBICULACEA

\* *Cyclas fontainei*. 1842: p. 569, pl. 83, figs. "16-17" (actually, 14-15). Guayaquil, Ecuador. B. M. no. 54.12.4.750, 2 specimens. *Neocyrena*. (Plate 1, Figures 20a-c).

#### VENERACEA

\* *Venus cycloides*. 1845: p. 562 (no fig.). Payta, Peru. New name for *Cytherea gigantea* PHILIPPI, 1844, ex SOWERBY, MS; not a homonym of *Venus gigantea* GMELIN, 1791 cited as *Cytherea* by LAMARCK, 1818. = *Dosinia ponderosa* (GRAY, 1838).

\* *Venus cumingii*. 1845: p. 563 (no fig.). Xipixapi, Ecuador. Type material not searched. Unneeded new name for the supposed homonym *Cytherea modesta* SOWERBY, 1835, non *Venus modesta* DUBOIS, 1831. Species figured and discussed by OLSSON, 1961, p. 280, pl. 46, fig. 4, as *Transennella modesta* (SOWERBY).

\* *Venus mariae*. 1845: p. 563 (no fig.). Isla la Plata, Ecuador. New name for *Venus cyprina* SOWERBY, 1835, non BROCCHI, 1814. Holotype, B. M., registry number not yet assigned. Species figured and discussed by OLSSON, 1961, p. 296, pl. 49, figs. 2, 8. *Chione (Lirophora)*.

\* *Venus paytensis*. 1845: p. 565 (no fig.). Payta, Peru; Cuming Collection, Xipixapi, Ecuador. Syntype lot,



B. M., labelled "West Colombia" (i. e. Ecuador), without assigned registry number. New name for the secondary homonym *Cytherea affinis* BRODERIP, 1835, non *Venus affinis* GMELIN, 1791 (both species now regarded as belonging in *Pitar*, s. l.). Apparently separable from *Pitar concinnus* (SOWERBY, 1835), as OLSSON, 1961, p. 288, has shown, ranging north at least to Panama. *Pitar* (*Lamelliconcha*). (Plate 1, Figures 8a-b).

- \* *Venus solangensis*. 1845: p. 564 (no fig.). Ecuador. Type lot in B. M., registry number not yet assigned. New name for the secondary homonym *Cytherea radiata* SOWERBY, 1835, non *Trigona radiata* MEGERLE VON MÜHLFELD, 1811, both species now regarded as *Tivela*. However, there is an available prior synonym. = *Tivela byronensis* (GRAY, 1838).

#### MACTRACEA

- \* *Donacilla chilensis*. 1845: p. 530 (no fig.). Not searched. = *Mesodesma donacium* (LAMARCK, 1818, *vide* OLSSON, 1961, p. 335).

#### TELLINACEA

- \* *Donax obesus*. 1845: p. 541, pl. 81, figs. 28-30. Payta, Peru. B. M. no. 54.12.4.702, 1 specimen. Holotype figured, OLSSON, 1961, p. 344, pl. 85, fig. 3.  
\* *Donax paytensis*. 1845: p. 541 (no fig.). Payta, Peru. B. M. no. 54.12.4.703, 4 specimens. Interior of one syntype figured by OLSSON, 1961, pl. 85, fig. 4. = *Donax dentiferus* HANLEY, 1843.

#### ACKNOWLEDGMENTS

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[In the following tabulation, the data on pages 131-132, on mollusks, are put into chronologic order instead of the order of the separate parts]:

Year	Pages	Plates
1834	1-48; 73-128	1-2, 9-13, 15-16, 56
1835	49-72; 129-176	3-8, 17-23, 25, 55
1836	177-184	14, 24, 26-28, 30-32, 34-35, 37, 58 [no dates on 33, 36]
1837	185-376	29, 38-52, 57
1838	—	—
1839	—	54, 59-66, 68-69
1840	377-424	53, 67, 70-71
1841	425-488	72-76, 79, 80 [possibly the "79" is a typographical error for 77, as there is a second 79 in 1847]
1842	—	83, 85 [no date on 84]
1843	—	—
1844	—	—
1845	529-600	—
1846	489-528, 601-728	—
1847	729-758 [no exact record of date]	78-79, 81-82

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# Foot Autotomy in the Gastropod *Gena varia*

(Prosobranchia: Trochidae)

BY

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(1 Text figure)

LARGE CONCENTRATIONS OF *Gena varia* A. ADAMS, 1850, a prosobranch gastropod usually typical for tropical regions, are encountered among the animals occurring under stones in the infratidal zone at Eilat (Red Sea, Israel). These gastropods are markedly photophobic and the slightest disturbance, e. g. merely trying to lift the stones under which they hide, puts them to flight. In attempting to escape, they plunge downwards and disappear among the algae and stones at the sea-bottom.

A prominent morphological feature of this genus is the large foot which extends posteriorly and cannot retract under the small ear-like shell (Figure 1).

A phenomenon rather unusual for mollusks was detected during collection of these prosobranch gastropods: when touched, they reacted by autotomy of that part of their foot which extended past the posterior margin of the shell. Immediately after, they attached firmly to a nearby stone, now completely covered by their shell.

The amputated part of the foot continued to exhibit movements for two to six hours after autotomy. Preliminary observations have clearly shown that the autotomy is not haphazard but always follows a well-defined course, occurring along the fine white line that traverses the foot. The region along this transverse line is histologically different from adjacent regions of the foot. Regeneration of the foot commences several days after autotomy.

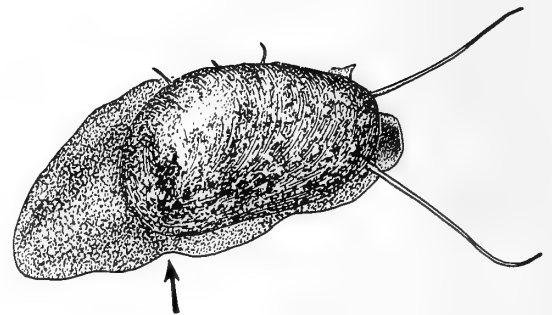


Figure 1

A living specimen of *Gena varia* A. ADAMS  
The arrow points to the narrow line of autotomy. x 2

Further histological and biological investigations should elucidate the cytological basis of this phenomenon as well as its biological importance.

This study is supported by contract 62558-4556 from the U. S. Office of Naval Research with the Department of Zoology, Tel Aviv University.

## A Description of a New Species of *Dirona* from the North-East Pacific

BY

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(Plate 2; 7 Text figures)

### INTRODUCTION

THE FAMILY DIRONIDAE was first described by COCKERELL & ELIOT (1905) and later by MACFARLAND (1912) giving a full account of two new species, *Dirona picta* MACFARLAND in COCKERELL & ELIOT, 1905 and *D. albolineata* MACFARLAND, 1912. Two more species have been added to the family: *D. pellucida* by VOLODCHENKO (1941) and *D. akkeshiensis* by BABA (1957), the latter species having been tentatively called *D. albolineata* in an earlier publication (BABA, 1935). A further note on *D. picta* has been made by VOLODCHENKO (1955) and additional information on this species and on *D. albolineata* has been provided by MARCUS (1961). A new species from the Puget Sound area possesses all the characters outlined for the family Dironidae and the genus *Dirona* but is clearly different from the previously established species in the following respects: general coloration, distribution of white markings, morphology of the egg mass, veligers, cerata, reproductive system (particularly the penis), size and proportions of radular teeth. It does not interbreed with the other local species, *D. albolineata*.

#### *Dirona aurantia* HURST, spec. nov.

The type specimens were collected by dredge between 11 and 30 fathoms west of Blakely Island and in West Sound in the vicinity of Friday Harbor Laboratories. *Dirona aurantia* has been previously dredged in the region at similar depths and one was observed on a float near the shore. Specimens have been most numerous in the winter months (September onwards) and have laid eggs in aquaria in January, February and March. They have sometimes been dredged with *D. albolineata* but in aquaria the two species do not associate and lay dissimilar egg masses (that of *D. albolineata* was described by O'DONOGHUE & O'DONOGHUE, 1922) giving rise to readily distinguishable veligers.

(It is intended to discuss further the eggs and veligers of these species in a later publication.) The narrow pink egg string of *D. aurantia* is laid in a loose coil, part of which appears in Plate 2, Figure 4.

The range of food taken by *Dirona aurantia* is wide. In one animal some apparent vegetable matter was found, in others were remains of hydroids and bryozoans, another's stomach was crammed with gammarids and caprellids, several being longer, though narrower, than the buccal region of the gut. It is likely that these crustaceans were eaten as dead or dying matter. *Dirona aurantia* lives well scavenging in aquaria. Unhealthy and dead specimens may be found with the buccal region protruded as described by COCKERELL & ELIOT (1905) in *D. picta*. This is an unnatural phenomenon: the feeding apparatus is such that it could not be effectively used in this position unlike that of some other opisthobranchs (HURST, 1965).

**Size:** Specimens have ranged in length from 3 to 12 cm. In an animal 7 cm long, the foot measured 6 cm and the oral veil 1 cm, the latter being wider than the foot (Plate 2, Figure 3). Thus *Dirona aurantia* may be longer than the greatest size recorded for other dironids (COCKERELL & ELIOT, 1905, MACFARLAND, 1912); however *D. albolineata* up to 12 cm has also been collected locally so that the length of 4.2 cm quoted for it by MACFARLAND (1912) is not maximal.

**Color:** The ground color is orange throughout (Plate 2, Figures 1, 2, 3, 4). Some specimens have occurred which were of a deeper reddish orange than those photographed here, but none were lighter. The body is scattered with white, granular spots (Figure 1, gr) though none appear on the underside of the foot or oral veil (Plate 2, Figure 3). A few isolated specks occur on individual cerata but here almost all the granules are concentrated in a tapering white line (Figures 1, 2, ce, gr), extending from a short distance above the ceratal base, up the median side and

surrounding the translucent tip completely. White granules are absent or scarce on the rhinophores (Figure 1, rh). The radiating white lines on the cerata are prominent in the living animal (Plate 2, Figures 1, 2, 4). The viscera may be seen by transparency through the underside of the foot as a dark brown mass (Plate 2, Figure 3).

**General appearance:** The animal is limaciform with a broad foot, rounded anteriorly and tapering posteriorly to a bluntly pointed tail (that part of the foot posterior to the bases of all cerata) which has a distinguishable dorsal ridge. This ridge is always white in *Dirona albolineata* but not in *D. aurantia*. The head is bluntly rounded (Figure 1) and around its anterior margin is the oral veil (or). This veil is thin, with very undulating edges, usually curving upwards medially (Plate 2, Figures 1, 3, 4). The mouth is a longitudinal slit mid-ventrally placed at the base of the oral veil (Plate 2, Figure 3).

The rhinophores (Figure 1, rh) point forwards and outwards at angles of about 120° with the back and with each other. The lower half of each rhinophore is stout and a little wider than the perfoliate terminal part. The

extreme tip is blunt and the rhinophore leaves are fairly regular and oblique, sloping forward and up from a mid-dorsal posterior separation. There are usually a few more than 20 leaves.

The cerata (Figures 1, 2, ce) are very numerous except in unhealthy specimens, in which they readily drop off (although they may be quickly regenerated). They are

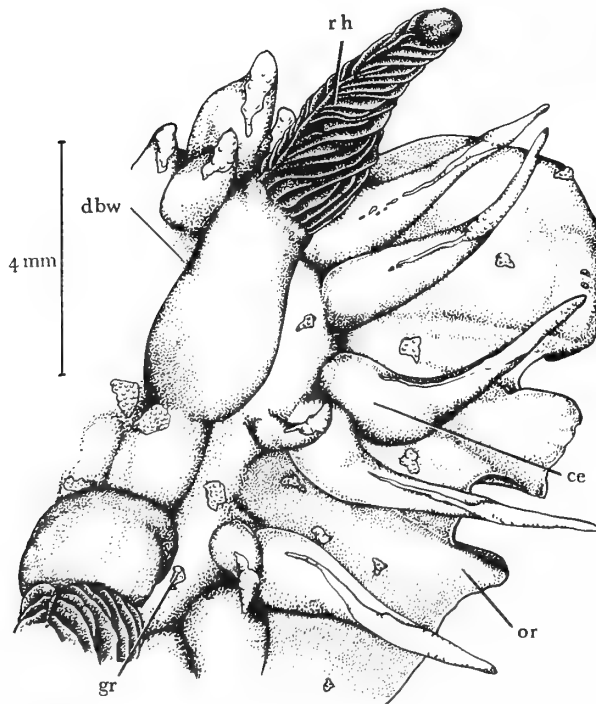


Figure 1

Right antero-dorsal view of the head region of *Dirona aurantia*.  
ce - ceras      dbw - dorsal body wall      gr - granules  
or - oral veil      rh - rhinophore

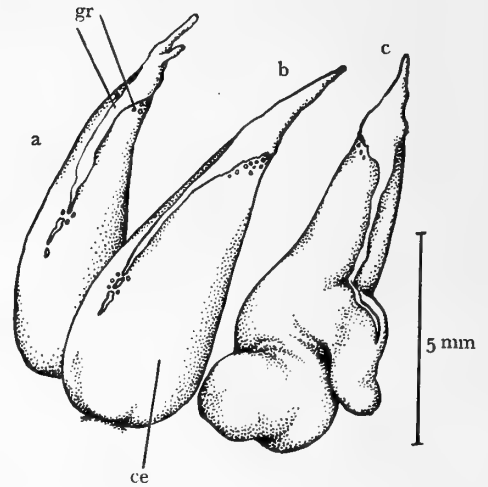


Figure 2

Median postero-lateral view of three cerata (a, b, c) of the right side of *Dirona aurantia*.

ce - ceras

gr - granules

based in a continuous series (but for a median anterior gap between the rhinophores) from anterior to the rhinophores along the sides and meeting over the dorsum at the base of the tail. The outermost cerata are abundant and very small. Median to them the cerata are larger and fewer, slightly flattened antero-posteriorly (less markedly than in *Dirona albolineata*) and much swollen above the narrow base. The largest occur on the posterior half of the body and often obscure this region of the back (Plate 2, Figure 2). Sometimes a few small cerata occur amongst the innermost cerata, unlike *D. picta* and *D. albolineata* (MacFarland, 1912). They are probably regenerating after the loss of some large cerata. A few cerata may be bifid (Figure 2, a) and some (rarely) are bluntly branched or very irregularly swollen (Figure 2c). All are smooth and muscular, continuing to contract vigorously when detached.

The reproductive openings lie about  $\frac{1}{4}$  of the way back from the head, on the right side below the cerata. The female opening is surrounded by radiating folds and is



Figure 1



Figure 3



Figure 2



Figure 4

Figure 1: *Dirona aurantia* HURST. Dorsal view of holotype.

Figure 2: Collection of six *Dirona aurantia* HURST from off Blakely Island and from West Sound.

Figure 3: *Dirona aurantia* HURST, ventral view.

Figure 4: *Dirona aurantia* HURST and part of its egg mass.

The parent was disturbed when only a small part of the mass was laid.





stretched widely during egg laying. Halfway along the right side immediately below the outermost cerata is the small renal aperture. The anus, as in other dironids, is raised on a stout papilla amongst the most posterior cerata of the right side. The papilla is cylindrical with longitudinal folds allowing considerable expansion during passage of faeces.

**Internal anatomy:** The mandibles (Figure 3) are large, completely enclosing the sides of the buccal region of the gut (Figures 3, 7, wj), closely hinged anteriorly (aj, al).

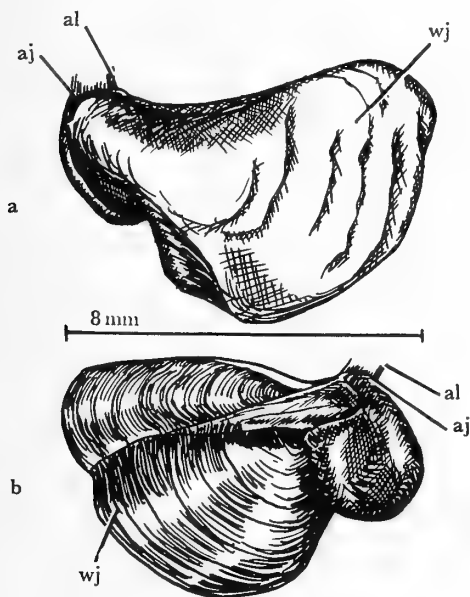


Figure 3

Left mandible of *Dirona aurantia* in

- a) outer lateral view                      b) median lateral view  
aj - articular region of jaw    al - articular ligament of jaw  
wj - lateral wing of jaw

They are very stout and of similar form to those of *Dirona picta* and *D. albolineata* described and drawn by MACFARLAND (1912). In all dironids the jaws serve as an important area for attachment of muscles concerned in the feeding process.

The radula from which Figure 4 was drawn has the formula 2.1.2x24-26. Some specimens have less rows of functional teeth, the minimum observed being 2.1.2x12-15. As in other dironids the short horizontal radular sac lies dorsally, above the bulk of the buccal mass. That part of the radular membrane bearing functional teeth curves down anteriorly and is folded longitudinally forming a

deep groove at the base of which are the median teeth (Figure 4, mt). They are widely separated from the rows of lateral teeth (1lt, 2lt) situated at the upper edges of

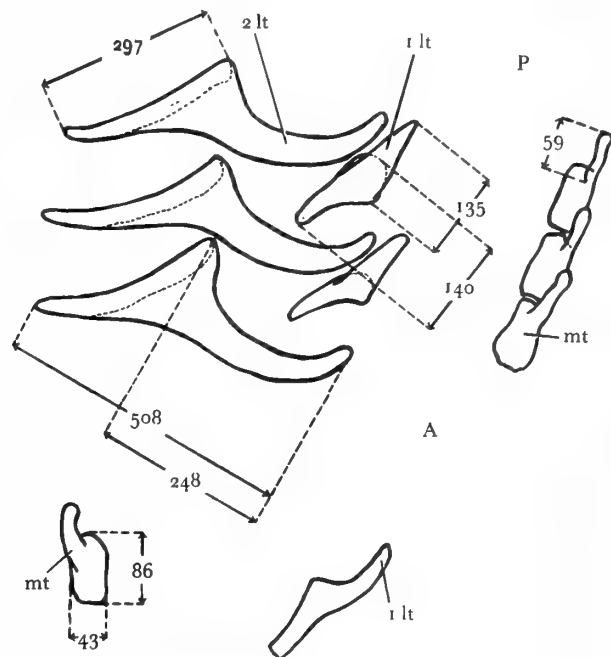


Figure 4

Radular teeth of *Dirona aurantia*.

A - anterior    1lt - first lateral tooth    2lt - second lateral tooth  
mt - median tooth    P - posterior

the groove where the radular membrane is reflected over the buccal mass. The teeth are larger than their counterparts in *Dirona picta* and *D. albolineata*, measured by MACFARLAND (1912) and MARCUS (1961), but as MARCUS noted tooth size varies with that of the whole animal. The form of the teeth is similar to that of other dironids. Each median tooth (mt) has a peg-like, back-pointing spine arising from a roughly rectangular base. Each first lateral tooth (1lt) has a simple spine pointing medially and backwards, converging at its tip with that of the adjacent second lateral tooth (2lt) of the same row. The large second lateral tooth is flattened and hamate, bluntly pointed and curves slightly backwards towards the median line.

The penis (Figures 5 A, 6, pc) is large and wide except at the tip which narrows abruptly to a short smooth papilla (pp). It is readily distinguishable from those of

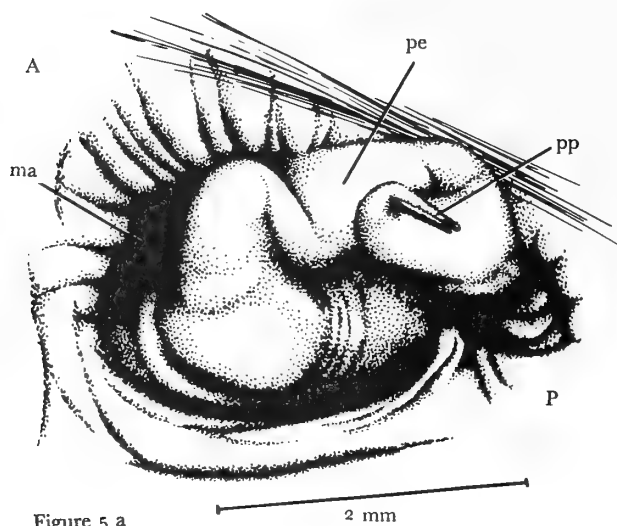


Figure 5 a

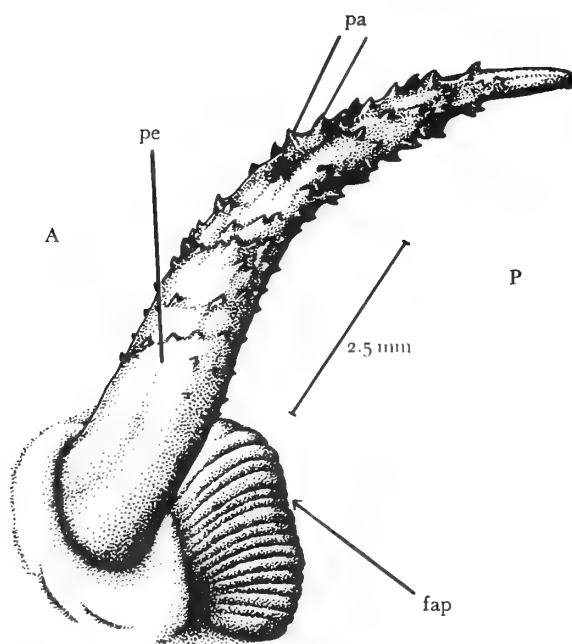


Figure 5 b

Figure 5

Penis of

- a) *Dirona aurantia* (retracted)    b) *Dirona albolineata* (extended)  
 A - anterior    P - posterior  
 fap - female aperture    ma - male atrium  
 pa - penial armature    pe - penis    pp - penial papilla

*Dirona picta* drawn by MARCUS (1961), *D. akkeshiensis* drawn by BABA (1935) and *D. albolineata* (Figure 5B, pe). The reproductive tract (Figure 6) is of essentially the same plan as that of these two species as described by MACFARLAND (1912) and further by MARCUS (1961). The spermatheca (Figure 6, sp) is large, its duct continuous with the very large muscular female atrium (fa). The oviduct (ov) is narrow and short, closely applied to the female gland mass (fg) and joining the wide terminal part of the hermaphrodite duct (hd). The long coiled vas deferens (vd) is stout but narrow and passes between the fibres of the penial retractor muscle (Figures 6, 7, pr) before entering the penis (Figures 5A, 6, pe). The penial retractor (Figures 6, 7, pr) passes anterior to the digestive gland (Figure 7, dg) to its origin on the left side of the body wall (bw). Its insertion on the muscular male atrium (Figures 5A, 6, ma) lies among the muscle fibres (Figure 6, am) surrounding the genital region (Figure 7, ge) of the body wall (bw).

The nervous and digestive systems (Figure 7) are rather similar in disposition to those of *Dirona picta*, described by MACFARLAND (1912). The destinations of the nerves are almost identical and apart from cerebral nerves 5 (Figure 7, c5), their paths are alike. In *D. picta* cerebral nerve 5, the optic nerve, "is closely attached to the anterior margin of c6 (or pl. 1)" (MACFARLAND) but in all specimens of *D. aurantia* examined, this was only true of the nerves of the right side, while on the left side the optic nerve (c5) was separate for its entire length. Pleural nerve 1 (pl 1), as noted by MACFARLAND in *D. picta*, may have a cerebral origin. The ganglia lie very close to the dorsal body wall. The thin-walled oesophagus (oe) is usually flattened on top of the buccal region of the gut as in Figure 7, passing back shortly to the stomach (st) on the left side of the body. The buccal ganglia lie below it, concealed in Figure 7. The buccal nerves are similar in distribution to those of *D. picta* figured by MACFARLAND.

The collection of specimens of *Dirona aurantia* from which the above description is taken is deposited at the California Academy of Sciences, Invertebrate Zoology Type Series, Holotype no. 273.

Geographical locations in Puget Sound from which specimens were taken:

W. Blakely	16 - 18 fathoms	48° 33' N	122° 49.9' W
W. Blakely	30 - 23 fathoms	48° 34.5' N	122° 50.6' W
West Sound	22 fathoms	48° 36.1' N	122° 57.9' W
Broken Point	11 - 12 fathoms	48° 35.4' N	122° 57.4' W

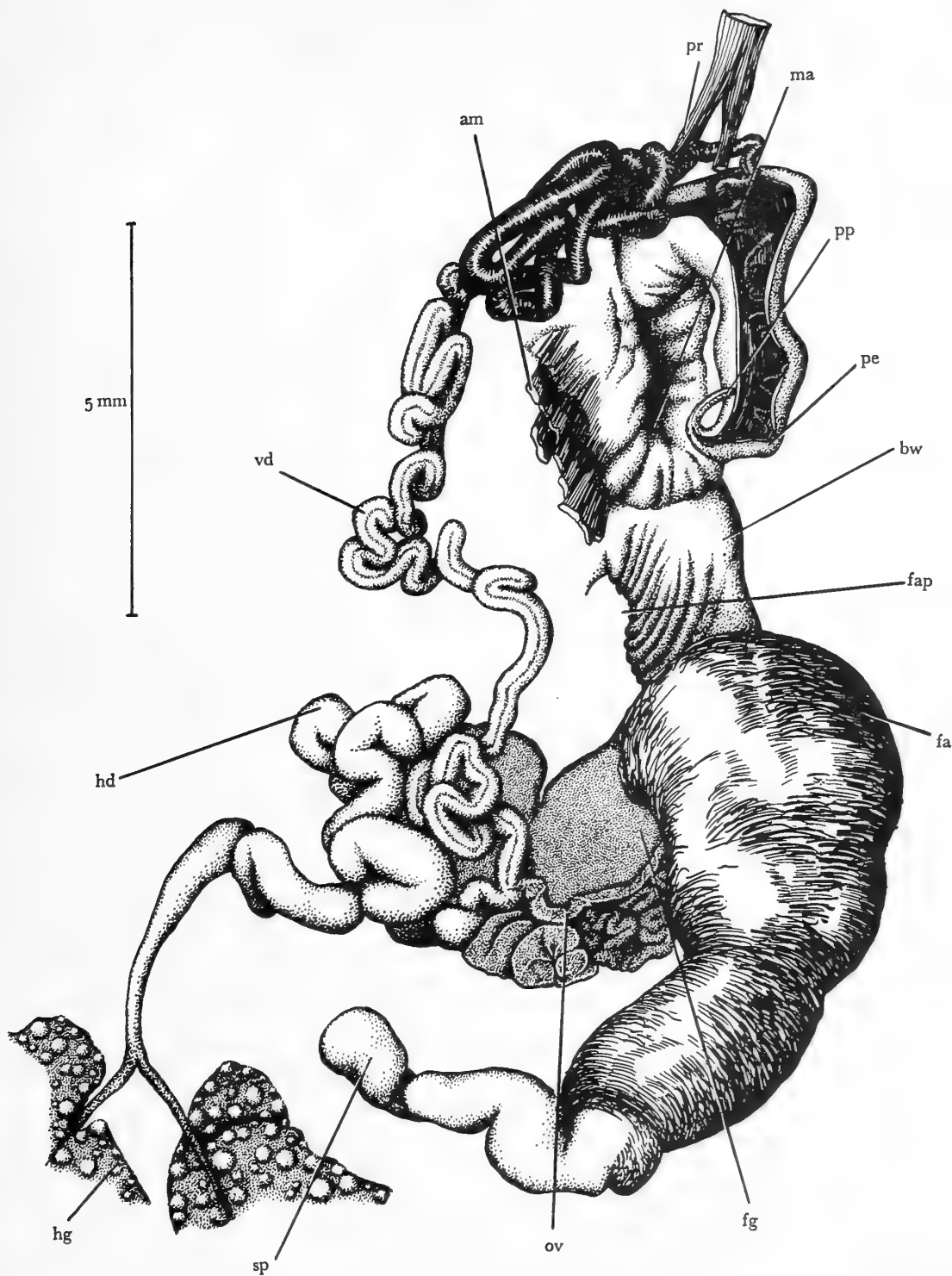


Figure 6

Dissection of the reproductive system of *Dirona aurantia*:

penis opened by a longitudinal cut; only part of the hermaphrodite gland shown.

am - atrial muscles  
bw - body wall  
fa - female atrium

fap - female aperture  
fg - female gland  
hd - hermaphrodite duct  
sp - spermatheca

hg - hermaphrodite gland  
ma - male atrium  
ov - oviduct  
vd - vas deferens

pe - penis  
pp - penial papilla  
pr - penial retractor

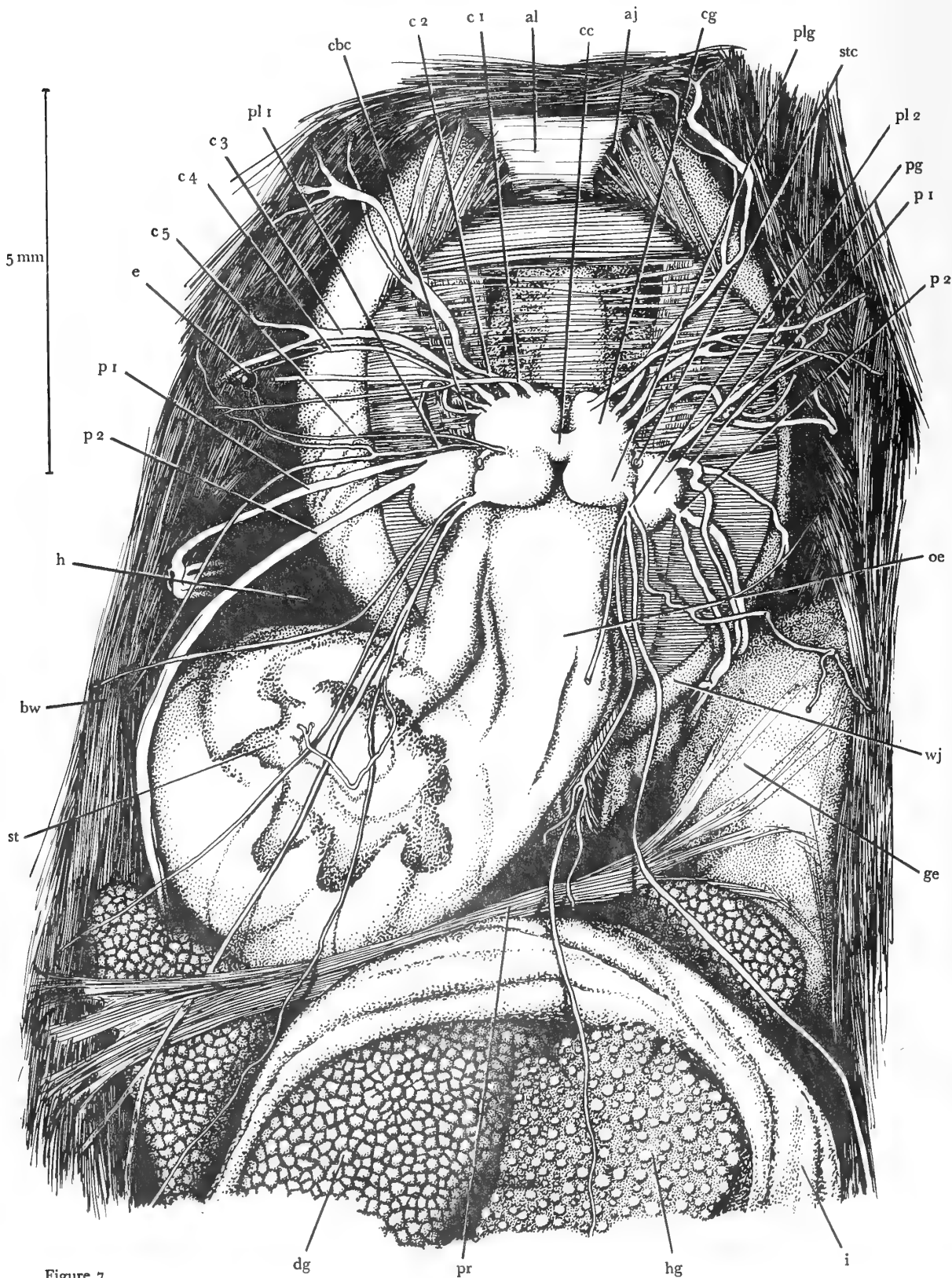


Figure 7

## ACKNOWLEDGMENTS

I am indebted to Dr. R. L. Fernald for the use of facilities at the Friday Harbor Laboratories and to the National Science Foundation for financial support. Thanks are due to Dr. K. M. White who confirmed identification of the animal described.

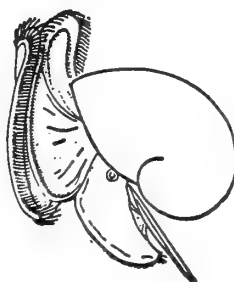
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Figure 7  
(facing page)

Dorsal view of a dissection of *Dirona aurantia* to show the major part of the nervous system and the anterior part of the gut *in situ*.  
(The numbering of the nerves follows MacFarland's (1912) description of the nerves of *Dirona picta*.)

- |                                 |                          |                          |                              |
|---------------------------------|--------------------------|--------------------------|------------------------------|
| aj - articular region of jaw    | cc - cerebral commissure | h - haemocoel            | pg - pedal ganglion          |
| al - articular ligament of jaw  | cg - cerebral ganglion   | hg - hermaphrodite gland | pl 1, pl 2 - pleural nerves  |
| bw - body wall                  | dg - digestive gland     | i - intestine            | plg - pleural ganglion       |
| c1-c5 - cerebral nerves 1-5     | e - eye                  | oe - oesophagus          | pr - penial retractor muscle |
| cbc - cerebro-buccal connective | ge - genital region      | p 1, p 2 - pedal nerves  | st - stomach                 |
|                                 | stc - statocyst          | wj - lateral wing of jaw |                              |



# *Rumina decollata* (LINNAEUS, 1758) (Achatinidae)

## Discovered in Southern California

BY

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(1 Text figure)

*Rumina decollata* is of Mediterranean origin and probably was introduced into the United States in the early 1800's. Prior to the present finding it was known to occur at many localities across the southern United States from the Atlantic seaboard to Yuma Mesa in Arizona. It is an omnivorous plant feeder and is cannibalistic on its own and other mollusk species. The decollate snail is not easy to detect because of its rather inconspicuous size (particularly of juveniles) and earth color, and because it burrows into the soil presumably to avoid dehydration and to feed on subterranean plant tissue.

The quarantine status of *Rumina decollata* as a potential pest in California is set forth in the State of California Department of Agriculture Quarantine Memorandum E-83 (1958). The main reason for submitting this note is to solicit the assistance of those with malacological interests in reporting the occurrence of *R. decollata* elsewhere in the State.

The first infestation to be reported in California was in the city of Riverside. On January 12, 1966, Mr. Gilbert L. Challet, a technician in this Department, brought in four dormant specimens for determination which he had picked off the wall of his garage after a rain. County and state agricultural inspectors at once surveyed the immediate area and found that the infestation was restricted to seven properties in the same block. No snails had crossed the streets to adjacent city blocks. Soon thereafter a press release with pictures of the snail was made and during the next week reports from interested citizens led to two more infestations in Riverside. Write-ups also appeared in adjoining counties, and the presence of colonies of *Rumina decollata* was verified in East Los Angeles, La Habra Heights, Claremont, Los Alamitos, and Costa Mesa. So far, positive findings have been reported only from areas where the news stories carried the picture of the snail. Snails were plentiful at all sites, usually on the surface of the ground or shallowly to partially buried beneath cover plantings such as ivy (*Hedera*), *Mesembryanthemum*, or in weed growth along fences. The largest infestation occurred over a recently subdivided 80-acre avocado orchard in La Habra Heights. Here, *R. decollata* coexists

with *Helix aspersa* MÜLLER and occurs mainly in beds of *Mesembryanthemum*.

Laboratory testing of various molluscicides is being conducted by Mr. Joseph Pappas (Department of Entomology, University of California, Riverside), and he has found that *Rumina decollata* is not killed by presently available commercial baits with metaldehyde, guthion, or zectran as the active ingredients.

From the size and distribution of the known infestations, and because of the known ages of housing developments on some of the sites, it is thought that *Rumina decollata* has been in southern California for at least 7 to 10 years. Consequently, eradication is no longer thought to be practical, and Californians will be obliged to learn to live with the decollate snail. Its chief mode of entry into the State is not difficult to deduce, particularly when the occupant of one property admitted bringing in potted ferns from an infested area in Arizona. A few such instances of smuggling past border quarantine inspectors, followed by exchanging of plants among gardening enthusiasts within the state, and . . . . . enough said.

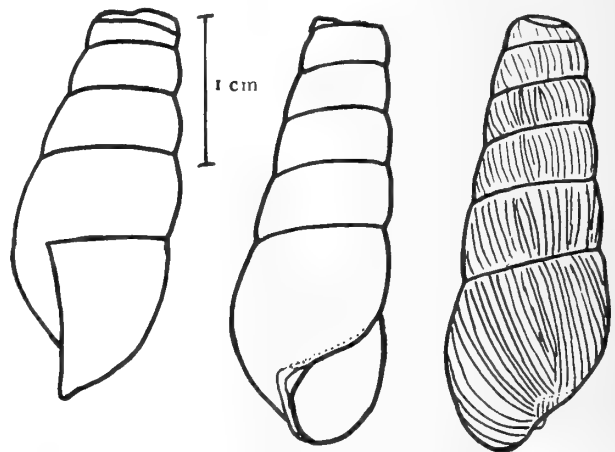


Figure 1

*Rumina decollata* (LINNAEUS, 1758): Sketch of shell from three aspects. The decollate shell is the "tip-off."



# Function of Labial Spines, Composition of Diet, and Size of Certain Marine Gastropods

BY

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(2 Text figures)

## INTRODUCTION

THE MORPHOLOGICAL BASIS of prey capture and penetration in many predatory marine prosobranch gastropods is fairly well documented: shell drilling by radular action and accessory boring organ (CARRIKER, 1955, 1961), harpooning with poisonous barbs (KOHN, 1959), and the use of the shell margin as a wedge (PAINE, 1962; WELLS, 1958b). It is surprising that little is understood of the functional significance of the most conspicuous external trait of apparent use in feeding: the single spine or labial tooth on the outer margin of the shell lip characterizing certain species in the Thaididae, Muricidae and Fasciolaridae. Generalizations in the literature, apparently unsupported by data, state that the spine is thrust between the prey's valves, preventing closure and hence facilitating consumption by the predator (MACGINITIE & MACGINITIE, 1949). The data given below suggest that this generalization, while possibly correct in some instances, does not appear to hold for those species with the most conspicuous spines. An understanding of spine function is closely related to the effects that organism size and behavioral capabilities have on food consumption. Field data on both intra- and inter-specific dietary variations have been assembled to provide a basis for comparisons of different spine-bearing species.

I wish to acknowledge the able field assistance of Charles King, Garrett Paine, and especially Fay Wolfson. Dr. Rudolf Stohler kindly identified the gastropod species and has generously loaned specimens in the collections of the Department of Zoology, University of California at Berkeley. The manuscript has benefited from the critical comments of Dr. A. J. Kohn. The University of Washington, through the offices of the Organization for Tropical Study financed the trip to Costa Rica. The field work in Baja California, Mexico, was supported in part by the National Science Foundation (GB-341).

## Specific Use of the Spine

Direct observations of spine use in the natural setting are difficult and tedious to make, and most of the present conclusions are based on inference, though wherever possible, supported by laboratory observation.

### *Acanthina brevidentata* (Wood, 1828)

This species, on the basis of 80 observations at two stations on the Pacific coast of Costa Rica, was seen to feed mainly (75%) on *Chthamalus* sp., although small individuals of other barnacle species may well be consumed. The remainder of the observed diet consisted of small mussels. The spine is well formed, though relatively short, being about 1 mm in length in individuals 2 cm long. The snail penetrates barnacles by drilling between their opercular plates. No evidence was obtained for spine use, although both drilling and prying the prey open with the spine would be redundant acts.

### *Acanthina tuberculata* (SOWERBY, 1835).

Despite the local abundance and large size (to 6-7 cm) of this intertidal species in the upper Gulf of California, I have rarely found it feeding. The spine is short (1-2 mm), often just a fold in the margin. In eight of fourteen feeding observations (57%) the carnivorous gastropod *Acanthina angelica* was the prey. There was no evidence of shell drilling in these prey; rather parts of the prey's operculum appeared to have been rasped away. In four instances limpets, *Crucibulum* sp., were being consumed. Again there was no evidence of drilling but in these cases the outer margin of the prey's shell had been shattered, probably by the *Acanthina's* shell. Casual observations on a 6 cm individual maintained in captivity for over 2 years indicate no deviation from the field pattern: operculate gastropods seem to be the preferred food of a variety offered, and are penetrated by having a corner of their operculum rasped away while being held in the *A. tuber-*

*culata*'s foot. I have never obtained any evidence that large individuals can drill, or that the spine is used. In fact, most gastropod prey withdraw so deeply into their shells that the short labial spine would be functionless.

*Acanthina angelica* (I. OLDROYD, 1918).

This species is widely distributed in the upper Gulf of California in intertidal waters (KEEN, 1958), and I have observed it at San Felipe, Puertocitos, and Puerto Peñasco. All observations to date suggest that it is a barnacle "specialist"; of 432 records of prey only two non-barnacles (both 10 mm individuals of the gastropod *Cerithium stercusmuscarum* VALENCIENNES, 1833) have been found. I have no data to indicate any strong prey preference being exercised within the abbreviated spectrum usually consumed, as is true for *Thais lapillus* (LINNAEUS, 1767) (CONNELL, 1961). For instance, at San Felipe in March, 1963 *Acanthina angelica* was observed eating the barnacles *Chthamalus* sp., *Tetraclita squamosa*, and *Balanus amphitrite*. These barnacles occupy recognizable zones and an estimate was obtained of the percent of *Acanthina* feeding in each area. There was no difference in feeding intensity where *Chthamalus* and *Balanus*, both small species, were abundant, 14/26 (54%) and 28/45 (62%) respectively of *Acanthina* picked at random actually feeding. On the other hand, only 48/120 (40%) of the individuals adjacent to *Tetraclita* were feeding. The reduced incidence may reflect some greater difficulty in penetrating these larger, thicker shelled, barnacles, but say little about food preference, since if the reward to the predator in terms of nourishment attained per unit time was greater, as might be expected from much larger prey, *Tetraclita* would be the optimal food.

In every instance the prey were being drilled, and characteristic holes were noted between the barnacles' opercular valves or in their lateral plates. Although *Acanthina* was observed during all stages of the feeding process, no function was noted for the apertural spine.

Another *Acanthina angelica* population was observed in March, 1964, at Puerto Peñasco, Mexico, on the opposite shore of the Gulf from San Felipe. The basic environmental situation appeared quite similar except that *Acanthina* appeared to be polymorphic for spine length. The majority of individuals were characterized by short (3 mm or less) spines and were eating *Chthamalus*. A number, however, characterized by immense (6-10 mm) spines were devouring *Tetraclita*, and it is from these latter individuals that a definite indication of the spine's function was obtained. Notice that all logical relationships between where the hole was drilled and the spine's position were encountered, although in far from equal frequency (Table 1). These data indicate that in only about

35% of the observations was the spine actually inside the opercular cavity of the barnacle, and that only 25% of the snails were feeding through the opercular plates. In the remaining instances both the spine and the point of active drilling were removed from the barnacle's natural opening. Five examples were noted (not recorded in Table 1) in which the spine was hooked around or in one barnacle, and the snail was feeding or drilling on a second. The conclusion seems inescapable that in these large-spined individuals the spine is used for purchase and is not directly involved in penetrating the prey.

Table 1

The relationship between spine position and hole position in a population of long-spined *Acanthina angelica* feeding on *Tetraclita squamosa*.

		Position of spine		
		Inside opercular opening	Outside opercular opening	Totals
Where barnacle was drilled	Outside opercular opening	8	30	38
	Inside opercular opening	10	4	14
	Totals	18	34	52

Twenty to thirty short-spined individuals from the upper Gulf have been maintained at Seattle, Washington, and laboratory observation obtained. After a varied period of starvation, these were offered *Balanus glandula* and the ensuing events were studied. The snails invariably spent some time orienting themselves on the barnacles. Then the spine, located between the eyes of a crawling snail, was hooked over the outside rim of the barnacle or in some convenient cranny, after which the barnacle was drilled. Although data were obtained from 15 different individuals, little variation in this procedure was noted, and never was the spine forcibly thrust between the prey's opercular plates. Seemingly the spine, as in the larger individuals, is used solely for purchase.

Spine length is quite labile in this species and varies from area to area. The relationship between shell length and spine length is compared in Figure 1 for the two most different populations yet examined and a third characterized by the longest spines. The former two

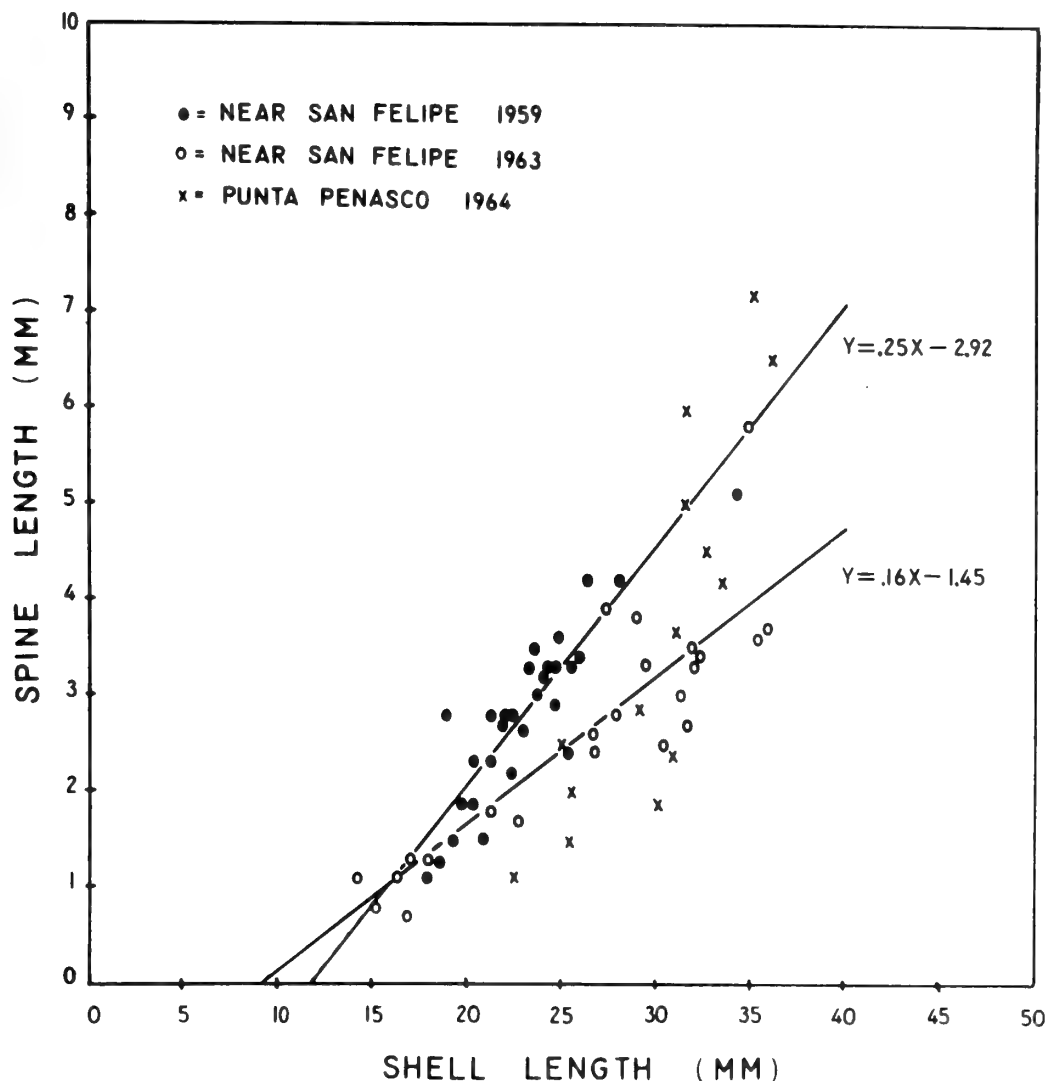


Figure 1

Spine-shell length relationships of three populations of *Acanthina angelica*.  
The significantly different regression lines were fit by least squares.

samples were collected approximately 30 miles south of San Felipe by Dr. R. Stohler. Regression lines fit by least squares indicate significantly different relationships between shell length and spine length within a local area, but sampled four years apart. Such would occur if spine length varied in response to barnacle size, and the barnacle species composition had changed gradually in this local area from 1959 to 1963. Both curves have similar

origins, reflecting the shell length at which the spine can be measured. The situation at Puerto Peñasco is rather different. Inspection of Figure 1 suggests a curvilinear relationship between the variables. However, the few points could also be interpreted as a composite of two linear relationships, one from approximately 10 to 30 mm shell length, the other from 30 to 37 mm. It is tempting to suggest that the shorter spined individuals were probably

eating small barnacles while the longer spined ones were consuming mature *Tetraclita*. Further field data are needed to resolve the reality of such a polymorphism.

*Opeatostoma pseudodon* (BURROWS, 1815)

KEEN (1958, p. 416) has stated that this member of the Fascioliidae has "... perhaps the longest apertural tooth developed by any gastropod," and of the species for which I have data, this assertion is borne out by high spine-shell length ratios. For instance, a shell 40 mm long may bear a 14 mm spine. My observations were all made at El Coco Beach on the Pacific coast of Costa Rica in July, 1964, where *Opeatostoma* was found living under rocks semi-buried in coral sand. Observations suggest it to be active nocturnally.

The species seems to be mainly verminivorous, although other items may well be eaten. In an examination of about 85 individuals during daylight hours, only 3 were found feeding. One of these was definitely consuming a serpulid polychaete. The remaining two were both firmly anchored in the sandy substrate by their immense spines, apparently feeding on "sand tubes," although no worm remnants were observed. Nocturnal observations added three more instances of feeding on tubiculous polychaetes plus one example of a small bivalve being taken.

In the cases of positively observed feeding, there was no indication that the spine had ever been brought directly to bear on the prey, and in fact, the spine's length (up to 15 mm) would mitigate against this. I feel that the spine

Table 2

New and literature accounts of size-feeding relationships of the Fascioliidae.

(G) indicates gastropod prey; (B), bivalve prey.

PAINE (1963) gives a breakdown to species of the categories listed.

Species	Adult length (cm)	Natural diet	% of total diet in category	Number of observations	Source
<i>Fusinus</i> spp.	4	polychaetes	100	11	this paper
* <i>Opeatostoma pseudodon</i> (BURROWS)	4.8	polychaetes small bivalves	86 14	7	this paper
<i>Fasciolaria hunteria</i> (PERRY)	8	polychaetes gastropods small bivalves carriion	41 13 32 13	76	PAINE, 1963
<i>Pleuroploca</i> ( <i>Fasciolaria</i> ) <i>filamentosa</i> (RÖDING)	10	<i>Calliostoma</i> (G) and a <i>murex</i> (G)		2	RISBEC, 1932
<i>Pleuroploca</i> ( <i>Fasciolaria</i> ) <i>trapezum</i> LINNAEUS	13	<i>Margaritifera</i> (B)			<i>vide</i> GRAHAM, 1954
<i>Fasciolaria tulipa</i> LINNAEUS	17	bivalves large gastropods carriion <i>Strombus</i> (G)	25 67 8	52  frequent	PAINE, 1963 ROBERTSON, 1961 RANDALL, 1964
<i>Fasciolaria princeps</i> SOWERBY	23 - 30	<i>Hexaplex</i> (G)			SORENSEN, 1943
<i>Pleuroploca gigantea</i> KIENER	35	bivalves large gastropods <i>Melongena</i> (G)	20 80	66	PAINE, 1963 HATHAWAY & WOODBURN, 1961

\* spine bearing species

functions in anchoring the animal to the coral rubble substrate, and is not directly involved in prey penetration.

### Size and Diet

The basic fact that, other things being equal, larger organisms need more energy for maintenance, is expressed at both inter- and intra-specific levels when dietary comparisons are made.

The Fascioliidae are carnivorous gastropods lacking any drilling apparatus, which penetrate prey by forcefully inserting the proboscis into the prey, often accompanied by mild rasping with the radula or use of the shell margin (WELLS, 1958a; PAINE, 1963). The family is well suited for studies on size-diet relationships because it includes *Pleuroploca gigantea* (KIENER) reputed to be the largest living carnivorous gastropod. Table 2 summarizes all available comparisons of size and diet. The *Fusinus*, observed near Puertocitos, consumed small serpulids by inserting the proboscis down the worm tube, a food-getting stratagem also characterizing *Fasciolaria hunteria* (PAINE, 1963). The observations on *Opeatostoma* indicated that tubicolous worms were its principal prey. In the 6 larger species the diet is composed of either bivalves or gastropods and no worms are consumed. In the Fascioliidae, then, smaller species eat polychaetes, and an increasing reliance on bivalves and gastropods, both more substantial food items, occurs with increasing size.

Similar interspecific trends characterize the Thaididae and Muricidae, considered jointly in Table 3 because of their close taxonomic position and common possession of a shell-boring mechanism. These data include only my

observations from the Pacific coast of Costa Rica (*Acanthina brevidentata*, *Thais kiosquiformis* (DUCLOS, 1832), *Thais biserialis* (BLAINVILLE, 1832), *Thais melones* (DUCLOS, 1832)) and the northern end of the Gulf of California (the remaining species named in Table 3). The general impression that the smaller species are barnacle specialists, or at least eat few other gastropods, would be supported by the work of CONNELL (1961) on other *Thais* species, and HEWATT (1934) on *Acanthina* sp. The very high percentage of gastropods in *A. tuberculata*'s diet may be due to relatively few observations on mainly large individuals, or may fairly indicate the high degree to which this species preys on *A. angelica*. The differences between *Hexaplex* and *Muricanthus* in regard to the proportion of barnacles taken is due to subtle habitat differences: although they are often found together, small *Muricanthus* live in cobble patches wherein barnacles abound. When only adults of both species are considered there is no change in the *Hexaplex* data whereas for *Muricanthus* the barnacle feeding incidence drops to 0% and the percentage of gastropods rises to 43%.

Both the above size-diet correlations include the tacit assumption that a particular species' post-larval diet is a fixed entity. The assumption is partially false, gastropod diets being known to vary geographically (THOMPSON, 1964) and presumably also during post-larval development. Enough data are available to examine intraspecific dietary changes related to size increase only in *Muricanthus nigrinus* (PHILIPPI, 1845). Observations made near Puertocitos in March 1962 and 1963, although pooled in

Table 3

The relationship between adult shell length and the relative contribution of barnacles and gastropods to a species diet. The asterisk indicates a spine-bearing species.

Species	shell length (cm)	Number of observations	% barnacles	% gastropods
<i>Morula ferruginosa</i> (REEVE)	2.5	39	100	0
* <i>Acanthina brevidentata</i> (WOOD)	3.0	80	80	0
* <i>Acanthina angelica</i> OLDROYD	3.9	432	99	1
<i>Thais kiosquiformis</i> (DUCLOS)	4.3	84	100	0
<i>Thais melones</i> (DUCLOS)	4.8	17	0	17
<i>Pterynotus erinaceoides</i> (VALENCIENNES)	5.0	7	0	14
* <i>Acanthina tuberculata</i> (SOWERBY)	6.2	14	0	89
<i>Thais biserialis</i> (BLAINVILLE)	7.5	99	23	18
<i>Hexaplex erythrostomus</i> (SWAINSON)	10.0	63	0	23
<i>Muricanthus nigrinus</i> (PHILIPPI)	2.0 - 15.0	118	34	29
	6.0 - 15.0	20	0	43

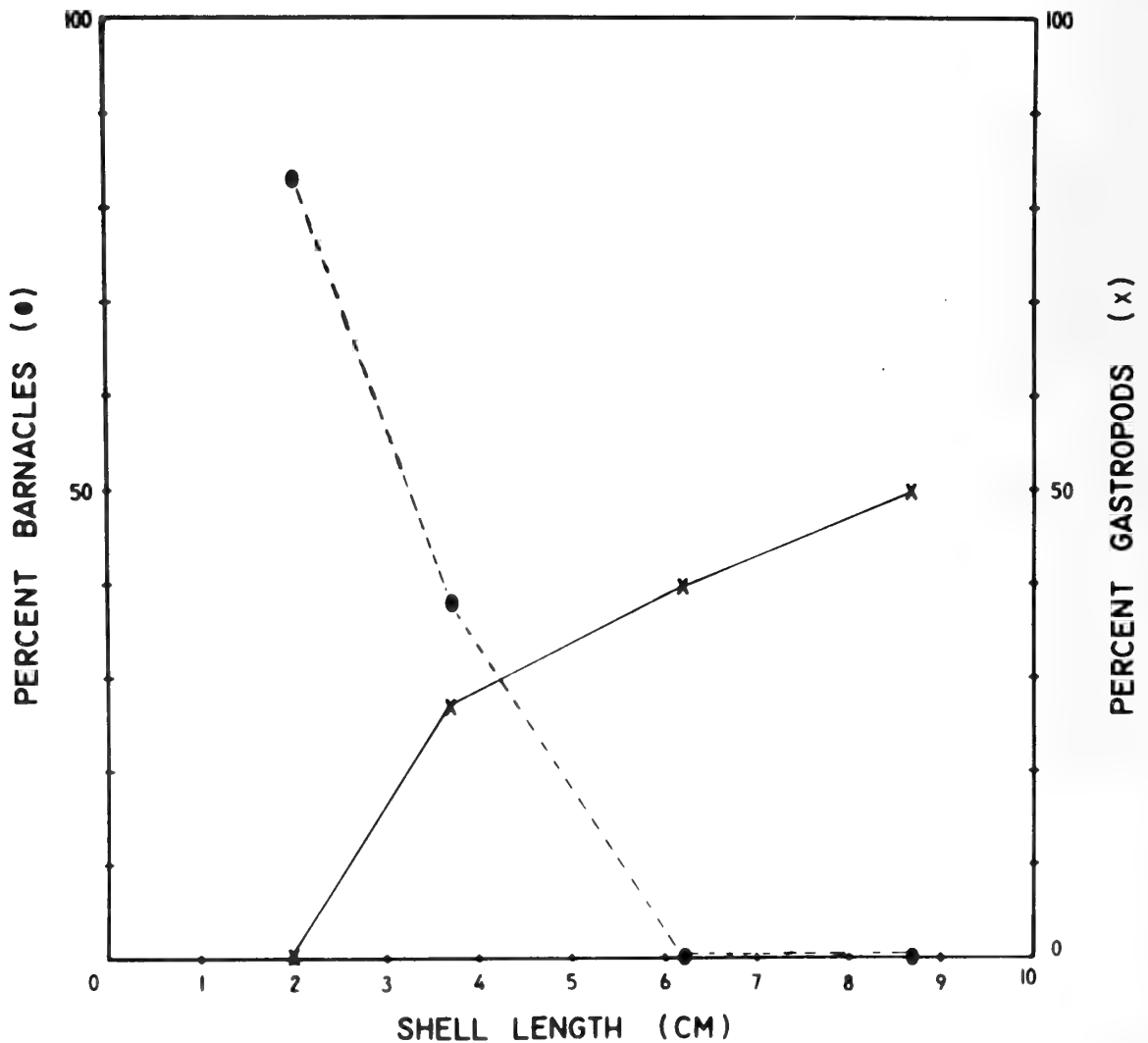


Figure 2

The changes in the relative frequency of barnacles (o) and gastropods (x) in the diet of *Muricanthus nigratus* with increasing size (= age).

Figure 2, show comparable trends when examined separately. There is a clear switch in diet with increased size, with the pattern being quite similar to that given in Table 3 for a haphazard collection of thaidids and muricids. Furthermore, inferences can be drawn about behavioral changes in the *modus operandi* of *Muricanthus* from observations on the prey at time of capture. Small *Muricanthus* drill barnacles, but with increasing size tend to use their shell lip to chip open prey. Some prey are still drilled, but at lengths greater than 5 cm shell use is

predominant. Thus, accompanying the ontogenetic change in diet is the acquisition of a new behavioral capacity not found in, or at least not used by, the smaller individuals.

#### Generalization and Conclusion

When the trophic capacities of varying species of gastropods are examined, a positive correlation between trophic position and an increased diversity of prey consumed may be found (PAINE, 1963). ELTON (1927) was apparently the first to recognize that these correlations with the pred-

ator's position were primarily due to an increasing relative scarcity of larger prey species which, in turn, tended to necessitate a more catholic diet if the predator's food requirements were to be met. This general tendency is clearly illustrated for adult members of the Muricidae and Thaididae (Table 3), in which increased shell length is accompanied by an apparently more diverse diet composed of larger prey organisms. The trend is clear in the Fascioliidae (Table 2) only if diversity is considered to be measured by the number of different higher taxa consumed. The proposition can be offered that these larger carnivorous gastropods are trophic generalists, within certain limits, attacking and consuming a greater variety of morphologically-different prey than do small species. In the Fascioliidae, small species use only the proboscis and larger ones both the proboscis and shell lip. In the Muricidae, small individuals drill while larger ones both drill and chip open their prey. Smaller species, eating a reduced variety of prey and probably characterized by fewer prey-penetrating mechanisms, may be called specialists.

Comparison of Tables 2 and 3 shows that those species with the longest spines, *Opeatostoma* and *Acanthina angelica* are of intermediate to small size, and both are specialists, one on worms, the other on barnacles. In both, the spine does not function directly in food gathering, but must have some adaptive function. In *A. angelica* I believe this to be the ability of snails with long spines to anchor themselves more firmly to the substrate while drilling. A firmer attachment could be maintained if the spine was inserted in a crevice, or barnacle opercular opening, and tension maintained against it, holding the snail more firmly to the surface. Since in intertidal communities large individual barnacles are usually zoned fairly high, and undoubtedly take longer to penetrate, a more secure "grip" on the prey would increase the probability of successful penetration by the predator without being dislodged, and would tend to minimize water loss on exposure to air.

The relative diminution or absence of spines in larger species may be considered a preadaptation, so to speak, foretelling the eventual abandonment of epifaunal sedentary prey. For instance, the short spine of the large species *Acanthina tuberculata* and *Murex fortispina* (FRANÇOIS, 1891), spines at best described as strengthened folds of the aperture, may be the result of potential feeding inefficiency associated with a large spine, when larger, specifically more diverse, prey are needed to meet the organism's nutritional requirements. Such prey usually must be dug (bivalves) or pursued (gastropods), acts in which a lengthy spine might prove detrimental.

In the context of the relationship of spine size, body length, and degree of dietary specialization within the Muricidae and Thaididae, there is a surprising degree of agreement between Figure 2 and Table 3 of the length at which gastropods begin to form a greater percentage of the diet than barnacles. In both the intra- and inter-specific comparisons this occurs at a shell length of 4-5 cm, suggesting some practical limit to the size at which energy expended in penetrating and devouring barnacles (or perhaps other small prey) is greater than the return for these efforts. Continued balanophagy or trophic specialization, then, above this size would be inefficient, and a switch in dietary emphasis appropriate to the general situation would be expected. The ecological consequences of these dietary changes, demonstrated for *Muricanthus*, cannot yet be explored since data on the diet of small individuals of most large species are unavailable. It seems clear that in *Muricanthus*, and generally in the Fascioliidae, Thaididae, and Muricidae, attainment of large size is accompanied by a switch in trophic position from that of a secondary consumer to higher status. What role this plays in the organization and stabilization of marine communities is unknown.

## SUMMARY

A combination of literature data with new observations indicates the reality of the expected correlation of both the diversity of, and general size of, prey with increasing body size within the gastropod families Fascioliidae, Muricidae and Thaididae. In the species *Muricanthus nigritus* the composition of the diet changes at a shell length of 4-5 cm from one in which barnacles have predominated, to one characterized by gastropods. A comparable switch characterizes the Muricidae and Thaididae, suggesting that specialization on small prey is only profitable energetically when the predator itself is small. Gastropods with a labial spine appear to be feeding specialists. The spine itself does not appear to function in prey penetration, but rather in anchoring the predator to the substrate.

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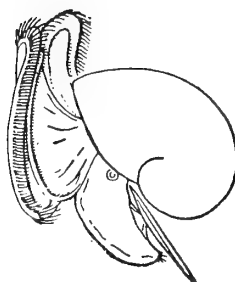
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## Muscular System of *Achatina fulica*

BY

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(Plate 3; 3 Textfigures)

THE MUSCLES in mollusks are unlike those in vertebrates and cannot be anatomically distinguished as voluntary and involuntary muscles. A physiological distinction, however, exists and they can be identified as somatic and visceral muscles, somewhat comparable to the voluntary and involuntary muscles of vertebrates respectively, at least from this point of view. In addition to constituting the entire columellar muscle complex, somatic muscles are present in foot, visceral stalk, tentacles, labial palps, buccal mass, penis, vas deferens and oviduct, while visceral muscles are restricted to the mantle, alimentary tract and other visceral organs. Both types of muscle fibres in *Achatina* are non-striate. Striped muscles recorded in the buccal mass and the ventricle of some gastropods are wanting here. Fibrils are, however, traceable in them (GHOSE, 1964).

### MATERIAL AND METHODS

Robust and healthy individuals of *Achatina* (*Lissachatina*) *fulica fulica* BOWDICH, 1822 were always used. For histological preparations muscles were collected from live specimens. For anatomical studies snails were killed by drowning, preserved in 50% ethanol or 6% formaldehyde for a few days and dissected. Standard fixatives were found suitable for sectioning.

### OBSERVATIONS

The fibres of the somatic and visceral muscles are fairly long, measuring approximately  $80 \times 7.2$  microns, with a centrally placed elongate-ovate nucleus bearing chromatin granules. The fibre is surrounded by a thin sarcolemma from which the contractile substance recedes slightly during fixation. Fibrils are very faintly visible only in some cases. In cross sections, some of the fibres appear triangular or rounded but the majority are oval in outline (Plate 3; Figures 1 and 2). An isolated, contracted somatic muscle fibre has a wavy contour.

### The columellar muscle complex:

The term "columellar muscle complex" has been used to include all muscle fibres which arise from one origin, or from more than one, but adjacent origins on the columella. In patelliform shells, like *Ancylus* and in slugs the columella is lost and the retractor may arise from diverse origins, which differ in number from one (a large ring as in *Lanx*) to many (some slugs). Their homologies are dubious.

The columellar muscle complex in the Achatininae is to the left (originally right?) of the hind gut and is considered as the left columellar muscle. It is divided into two large muscles - (1) the pedal retractor and (2) the free retractor system, having a separate but adjacent origin on the columella. They are placed side by side and

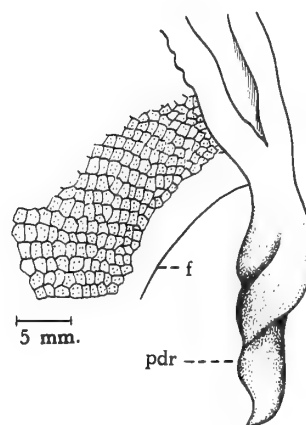


Figure 1

Pedal muscle with a part of the foot (side view) of *Achatina fulica*  
f - foot  
pdr - pedal retractor

attached to the columella at about the junction of the body-whorl and the penultimate whorl.

### The pedal retractor:

From the two laterodorsal and posterodorsal surfaces of the foot, ventral to the neck, the pedal retractor projects backward and gradually tapers for about 30 mm where it is spirally twisted (Text figure 1) and completes one full turn. This portion is attached to the columella and its spiral shape corresponds to the shape of the columella. The function of the muscle is to anchor the body

to the shell. It also helps in the contraction of the foot, but that must be very small.

### The free retractor system:

The free retractor system (Text figures 2 and 3) is proximally attached to the columella beyond the origin of the pedal retractor. The proximal 30 mm of the muscle is spirally twisted and completes  $1\frac{1}{4}$  turns. In this region the muscle is ribbon-like. Distally it divides into right and left retractors.

### Right free retractor:

This muscle has several branches running anteriorly to insert on the buccal mass, snout, vas deferens and anterior part of the foot.

#### 1. The penial retractor:

It arises from the medial side of the free retractor at a distance of about 25 mm from the origin on the columella and runs anterolaterally to end on the hair-pin loop of the vas deferens (GHOSE, 1963) at the posterior end of the penis. The quick withdrawal of the penis is effected by the contraction of the penial retractor. In addition to the normal type of insertion described above, the penial retractor may be a separate band unconnected with the free retractor, and is inserted either (a) on the right side of the diaphragm over the median haemocoelic chamber, or (b) bifurcates into two equal bands at a short distance from the penis and these are inserted into either side of the diaphragm, towards its anterior margin, or (c) shifts further to be attached to the left side of the dorsum of the foot near the neck. These observations are similar to what MEAD, 1950, described in *Achatina* spp.

#### 2. The right pedal retractors:

These are three in number, arise from the right side anterior to the root of the penial retractor and run anterolaterally. The first one divides into five branches while each of the second and third divides into two or three branches. The branches end on the ventrolateral wall of the foot at short distances along an anteroposteriorly directed line.

#### 3. The right ocular retractor:

Its origin is slightly anterior and ventral from the third pedal retractor. In its forward course it sends a median branch, the cerebral retractor, which unites with its fellow of the other side to form a transverse muscle on the posterodorsal part of the buccal mass. This is connected with the cerebral ganglia by a membranous sheet of tissue (GHOSE, 1962) and is responsible for pulling back the cerebral ganglia in a coordinated way with other

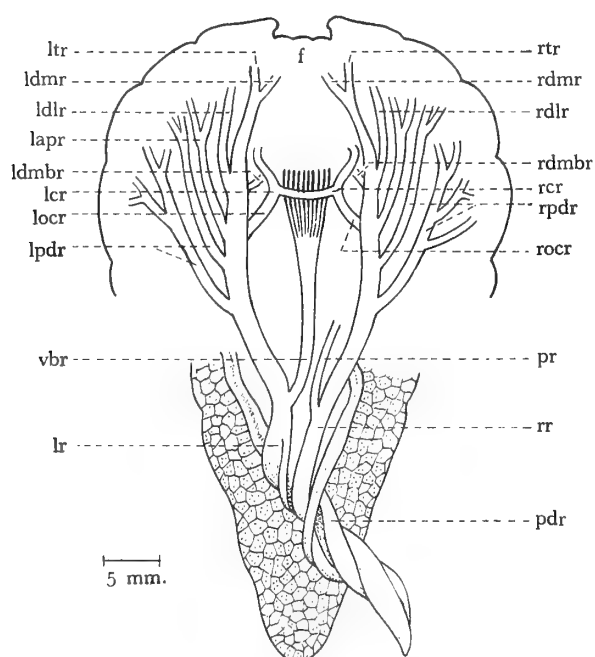


Figure 2

The free retractor system (diagrammatic) of *Achatina fulica* (dorsal view). Buccal mass and penis sheath removed

f - foot      lapr - left anteropodal retractor  
lcr - left cerebral retractor      ldlr - left dorsolateral retractor  
ldmr - left dorsomedial retractor      ldmbr - left dorsomedio buccal retractor  
locr - left ocular retractor      lpdr - left pedal retractor  
lr - left retractor      ltr - left tentacular retractor      pdr - pedal retractor  
pr - penial retractor      rcr - right cerebral retractor  
rdldr - right dorsolateral retractor      rdmr - right dorsomedial retractor  
rdmbr - right dorsomedio buccal retractor  
rocr - right ocular retractor      rpdr - right pedal retractor  
rr - right retractor      rtr - right tentacular retractor  
vbr - ventrobuccal retractor

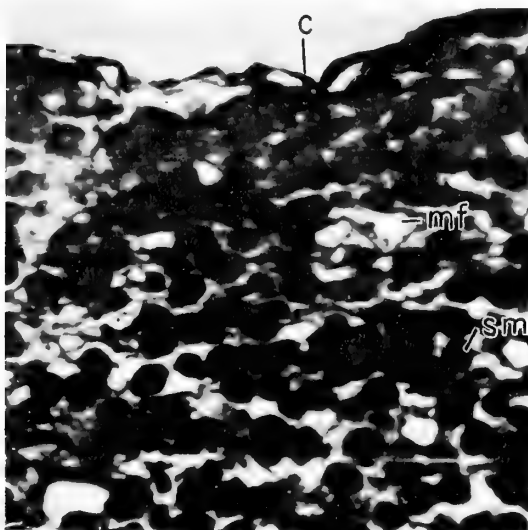


Figure 1

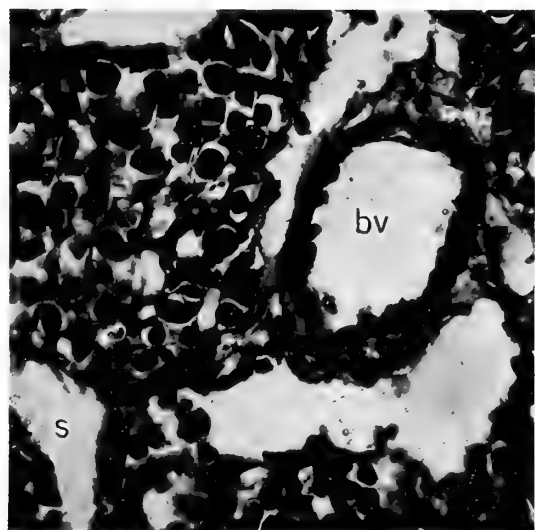


Figure 2



Figure 3

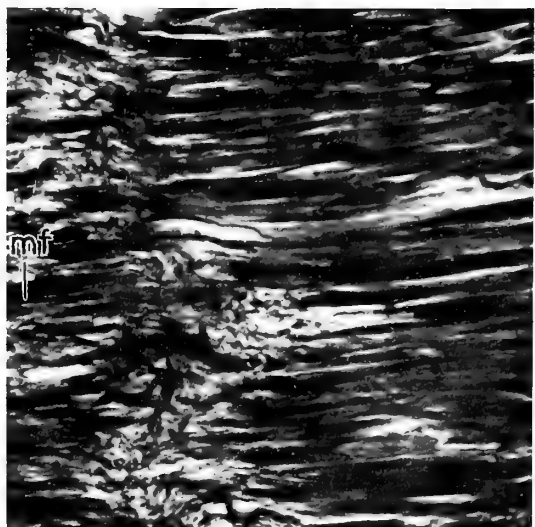


Figure 4

*Achatina (Lissachatina) fulica fulica* BOWDICH, 1822

Figure 1: Transverse section of a branch of the free retractor passing through a side

Figure 2: Transverse section of a branch of the free retractor passing through the middle

Figure 3: Longitudinal section of a branch of the free retractor passing through a side

Figure 4: Longitudinal section of a branch of the free retractor passing through the middle

bv - blood vessel   c - capsule   mf - muscle fibre   s - sinus   sm - sarcolemma



adjacent organs, so that nerves arising from the ganglia may not be damaged. The ocular retractor runs forward and becomes membranous and fan-shaped and divides into two. One branch ends on the wall of the ocular tentacle and the other branch passing through the ocular tentacle reaches its tip and is responsible for the retraction of the same.

#### 4. The right dorsolateral retractor:

It is unbranched, anterior to the third pedal retractor in origin, becomes membranous and fan-shaped and ends on the right dorsolateral wall of the snout.

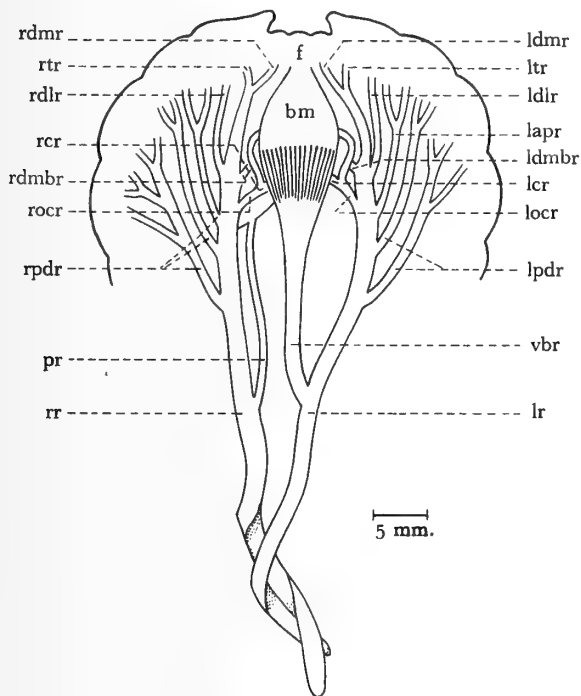


Figure 3

The free retractor system (ventral view) of *Achatina fulica*

- |  |   |                                   |
|--|---|-----------------------------------|
| bm - buccal mass                         | f - foot                                | lapr - left anteropedal retractor |
| lcr - left cerebral retractor            | ldlr - left dorsolateral retractor      |                                   |
| ldmr - left dorsomedial retractor        | ldmb - left dorsomedio buccal retractor |                                   |
| locr - left ocular retractor             | lpdr - left pedal retractor             |                                   |
| lr - left retractor                      | ltr - left tentacular retractor         |                                   |
| pr - penial retractor                    | rcr - right cerebral retractor          |                                   |
| rdlr - right dorsolateral retractor      | rdmr - right dorsomedial retractor      |                                   |
| rdmb - right dorsomedio buccal retractor | rpdr - right pedal retractor            |                                   |
| rocr - right ocular retractor            | rtr - right tentacular retractor        |                                   |
| rr - right retractor                     | vbr - ventrobuccal retractor            |                                   |

#### 5. The right dorsomedio buccal retractor:

A median branch, ventral and slightly posterior to the dorsolateral retractor in origin, it ends on the right dorso-medial side of the buccal mass at the posterior end and helps in the retraction of the same.

The main trunk now becomes membranous and divides into two branches.

#### 6. The right dorsomedial retractor:

This is a large median branch and ends distally on the right dorsal wall of the snout. It is membranous on the medial side and, uniting with its fellow of the other side, forms a complete dorsal covering over the buccal mass, ending on the tip of the snout anteriorly, and connected with the cerebral ganglia and adjacent nerves posteriorly. It helps in the retraction of the snout along with the nerve ganglia.

#### 7. The right tentacular retractor:

The second branch of this retractor divides into two. The median branch ends on the dorsolateral wall of the snout at its tip and the lateral branch on the right ventral tentacle.

#### Left free retractor:

It is stouter than the right one and has the following branches.

##### 1. The ventrobuccal retractor:

This stout median branch separates from the main trunk at about 30 mm forward from the origin on the columella. This muscle runs anteromedially, becomes membranous and fan-shaped anteriorly and divides into several branches to end on the ventral surface of the buccal mass, along the posterior margin of the buccal cartilage, anterior to the radular sac.

##### 2. The left pedal retractors:

Two in number, these retractors arise from the left side anterior to the ventrobuccal retractor. Their branches and the course are similar to their partners on the right side, but the branches of the first one end on the foot slightly posteriorly.

##### 3. The left ocular retractor:

This arises from the ventral surface of the main trunk anterior to the origin of the second left pedal retractor and runs forward. Its branches and the course are like those of the right ocular retractor.

##### 4. The left anteropedal retractor:

It arises from the left side of the main trunk close to the origin of the left ocular retractor and soon divides into two branches; the median one runs forward and, being

membranous, ends on the anterodorsal wall of the snout, towards the left, while the other branch runs laterally, becomes membranous and ends on the ventrolateral wall of the foot.

The main trunk of the left free retractor becomes membranous. Its subsequent branches and their courses are almost like those of the corresponding branches of the right one.

The band-like branches of the free retractor system of the columellar muscle complex are ensheathed in a very thin capsule formed by a single layer of flattened cells with inconspicuous nuclei. Many blood sinuses of irregular shape and size, as well as nerve fibres, are present in a muscle band. In a narrow zone, just inside the capsule, the fibres appear rounded in cross section (Plate 3; Figure 1). The longitudinal section of this zone reveals that the fibres are long, cylindrical and branched and they unite with one another to form a network (Plate 3; Figure 3). In the rest the fibres are comparatively short, cylindrical or spindle-shaped, being membranous towards the ends (Plate 3; Figure 4). This membranous portion undergoes maximum contraction.

In *Achatina* the right free retractor muscle is responsible for the retraction of the anterior right half of the snout with the structures lodged there, and the left free retractor for the retraction of the left half of the snout and the buccal mass.

Due to the contraction of the powerful columellar muscles, the ventral tentacles, ocular tentacles, snout and the anterior part of the foot are retracted. The retraction begins at the tip of the snout and gradually runs back-

wards. With the contraction of the columellar muscles, the intrinsic muscles of the foot also contract and the foot becomes shortened and wavy in outline. The visceral stalk contracts due to the contraction of its longitudinal muscles. By a coordinated contraction of the columellar muscles and those of the visceral stalk and foot, the animal very quickly withdraws itself completely within the shell.

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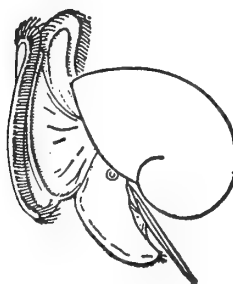
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## On *Donax* and Other Sandy-Beach Inhabitants

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WHILE ENGAGED IN a study of diseases of the bean clam *Donax gouldii*, I had the opportunity to make various ecological observations on this little clam and its co-inhabitants of the sandy surf-washed beaches of southern California and northern Baja California. This brief report will enumerate some of these observations which, to my knowledge, have not been recorded previously.

*Donax variabilis texasiana* PHILIPPI, 1847 and *D. fossor* SAY, 1822 from the new world and *D. semigranosus* DUNKER, 1877, of Japan have been observed to migrate up and down the beach according to the tidal level (TURNER & BELDING, 1947; MORI, 1938, 1950; JACOBSON, 1955; LOESCH, 1957). The clams "pop out" of the sand on the uprush of an incoming tide or backwash of the outgoing tide, travelling several feet or yards, then halting progress with the extended foot, they rapidly dig under the sand once again. *Donax gouldii* DALL, 1919, exhibits the same tendency but to a lesser degree than in species which may inhabit steeply sloping beaches in areas of great tidal differences. In the range of *D. gouldii* mean high and mean low water vary only one to three feet except at spring tides so the uncovered sand of the intertidal zone usually stays fairly wet. As well, the only stable bean clam populations I found were on gently sloping beaches where marked migrations with incoming or receding waves are not so possible. During neap tides at Estero Beach, Todos los Santos Bay, Baja California, I observed a scattering of gaping or dead, semi-desiccated bean clams along the high tide line where they must have been cast by the incoming tide as they migrated up the beach. One would assume *D. gouldii* is not particularly resistant to drying and in such an instance extreme tidal migrations can lead to disaster for the clams.

Almost all the dead and gaping clams mentioned in the preceding paragraph were hosts to one or more dipterous larvae. Some of the larvae were reared to adult stage and identified as the sarcophagid *Blaesoxipha californica*

(PARKER, 1918) by C. W. Sabrosky, Insect Identification Branch, U. S. Department of Agriculture. The stranded clams were not numerous and had been above the water line no more than four hours, testifying to the great skill of female flies in detecting the presence of animal remains.

Little is known of the life history of the colonial hydroid, *Clytia bakeri* TORREY, 1904, which occurs commensally on the shell of *Donax*. At La Jolla Beach, Todos los Santos Bay in October, 1964, only a very few members of a dense, young bean-clam population, had strands of *Clytia* on their shells. Their condition was similar in January, 1965. However, by August, 1965 almost every clam had a plume of *Clytia* and the hydroid itself supported a brown alga which covered the entire plume. At Estero Beach, about five miles north of La Jolla Beach and separated from it by the entrance to the Estero, an older *Donax* population was well provided with *Clytia* and its attendant alga during the entire period of observation. In another young population of *Donax* some miles north of Estero Beach even clams as small as 7 or 8 mm in length were heavily covered with *Clytia*.

The ideal habitat for *Donax gouldii* appears to be a very gently sloping beach with a certain amount of shallow sand-barring just beyond median low tide level. A beach of this type has firm, fine-grained sand which probably results in less abrasive action on the clams. The conditions occurring in the low tide zone of such open beaches are only marginally satisfactory for animals said to normally occupy sand flats (RICKETTS & CALVIN, 1962). Nonetheless, these beaches do support fair numbers of sand-flat animals. The sand collars (egg cases) of the moon snail, *Polinices reclusiana* (DESHAYES, 1839) are commonly seen at Belmont Beach, Newport Beach, Scripps Beach (at La Jolla, California), and farther south on the beaches of Todos los Santos Bay. Near Newport pier during summer, 1964, *Dendraster excentricus* (ESCHSCHOLTZ, 1831) and

*Olivella biplicata* (SOWERBY, 1825) were common, and several individuals of *Renilla koellikeri* PFEFFER, 1886, were found. At Belmont Beach and Scripps Beach I have observed sizable colonies of *O. biplicata* as well as extensive colonies in the shallow low-tide zone at Estero Beach. At both Scripps Beach and Estero Beach the number of drilled shells of *Donax* occurring together with living moon snails indicates *Donax* must serve as an important food source for this predaceous drill. Another snail, *Nassarius fossatus* (GOULD, 1849), was found once at Scripps Beach and several times at Estero Beach.

*Olivella biplicata* not only occupies the same intertidal zone as *Donax gouldii*, but at Belmont and Scripps beaches individuals were twice observed to regularly "pop out" of the sand where backwash created currents about one's feet. These snails travelled several feet seaward before extending the foot, anchoring themselves, and disappearing once again under the sand. In this habitat they closely approximated the actions of *Donax* in a similar situation and one may wonder if olive shells also perform tidal migrations.

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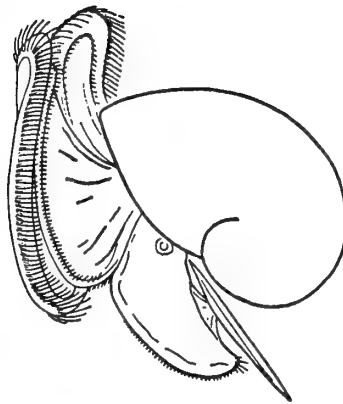
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## The Higher Taxa of Cowries and their Allies

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ACCORDING TO the International Rules of Zoological Nomenclature (July 1958) the family group of scientific names consists of the taxa superfamily, family, subfamily, and tribus (Article 35 a). They are named after and defined by a typical genus (Art. 35 b) by appending to the root of the generic name the syllables *-idae* and *-inae* for families and subfamilies obligatorily, but *-oidea* and *-ini* for superfamilies and tribus only by recommendation (Art. 29, 29 A). The first generic name chosen to represent the typical genus of a taxon of the family group automatically becomes the typical genus of any other taxon of the family group (Art. 36); this name need not be necessarily the oldest generic name belonging to the higher taxon (Art. 64). Later established taxa of the family group become synonyms of the taxa to which the genus belongs (Art. 23 d), but it seems advisable to cite them as synonyms of the lowermost distinguished taxa only. The author of names of the family group is the writer who first used a generic name to designate a higher taxon, even if the appended syllables do not agree with the official ones named above and therefore must be emended (Art. 36). The year of this first establishing a higher taxon is to be adopted for all other taxa of the family group based on the same typical genus (Art. 36).

The following list contains the generic names used as those of typical genera of taxa of the family group of the old, well known "genera" *Erato*, *Trivia*, *Pedicularia*, *Cypraea*, and *Ovula* (= *Amphiperas*); the taxa allied to *Lamellaria*, however, have been omitted.

In the first column the generic names have been arranged in chronological order according to the date of being used as typical genus of a taxon of the family group; the second column contains the names of the authors who used them in this sense, and the year of publication of the higher taxon; the third column indicates the exact original spelling of the higher taxon's name in their papers.

(see Table 1, next page)

In past times conchologists used to place the ribbed "*Trivia*" in the genus "*Cypraea*" on account of the aperture being denticulate on both lips, and the species of *Erato* have been placed among the Marginellidae, until anatomical research showed that *Trivia* and *Erato* are

closely allied to each other, and that both exhibit affinity to Lamellariidae. Therefore the three last named groups have been united as superfamily Lamellariacea even in the Zoological Record (beginning with vol. 76 for 1939), while the superfamily Cypraeacea has been restricted to the mostly smooth "*Cypraea*" and "*Ovula*" (= "*Amphiperas*"); *Pedicularia* has been placed into Lamellariacea (Zool. Record, vol. 84 for 1947).

However, I consider it to be more advisable to separate the Triviidae from the Lamellariidae on the rank of superfamily, as the latter show no distinct siphon, united jaws, a nautiloid (instead of a helicoid) echinospira larva, biological peculiarities, and the shell being covered by a periostracum (absent in all other allies), showing a sharply edged, never inflected outer lip also in the adult stage, and no traces of teeth along the wide aperture (SCHILDER, 1936, p. 106). Therefore I suggest that "cypraeologists" should restrict their studies to the superfamilies Triviacea and Cypraeacea and exclude the true Lamellariacea as I have done in the present paper.

I think that the ending *-acea* should be retained for superfamilies in malacology as it has been generally used since the publication of THIELE's handbook (1929), because the termination *-oidea* has not been proposed as obligatory, but only as a recommendation (Art. 29 A). IREDALE (1935, p. 97), however, used the term "*Cypraeoidea*".

There are several rather isolated aberrant genera which possibly could deserve to be separated as higher taxa; but I consider it more advisable to place them provisionally into a well known allied taxon even if thereby it becomes difficult to find common characters to be used in the dichotomous key.

Thus the higher taxa of Triviacea and Cypraeacea may be arranged according to Table 2. This arrangement mostly agrees with the phylogenetical trees published in previous papers, especially in SCHILDER, 1936 and 1939. The predominantly Recent genera of Lamellariacea should be arranged according to THIELE (1929, pp. 262 - 267).

In Table 2 the extinct taxa have been marked with a dagger (†); synonyms have been added by foot notes. Many synonyms established chiefly by the writer himself

Table 1

Typical Genus	Author of higher Taxon	Name of higher Taxon
<i>Cypraea</i>	GRAY, 1824	Cypraeidae
<i>Ovula</i>	FLEMING, 1828	Ovuladae
<i>Amphiperas</i>	ADAMS & ADAMS, 1854	Amphiperasidae
<i>Pedicularia</i>	ADAMS & ADAMS, 1854	Pediculariidae
<i>Trivia</i>	TROSCHEL, 1863	Triviacea
<i>Lamellaria</i>	TROSCHEL, 1863	Lamellariidae
<i>Porcellana</i>	ROBERTS, 1870	Porcellanidae
<i>Eocypraea</i>	SCHILDER, 1924	Eocypraeinae
<i>Erosaria</i>	SCHILDER, 1924	Erosariinae
<i>Erato</i>	SCHILDER, 1927	Eratoinae
<i>Cypraedia</i>	SCHILDER, 1927	Cypraediinae
<i>Cypraeovula</i>	SCHILDER, 1927	Cypraeovulidae
<i>Simnia</i>	SCHILDER, 1927	Archicypraeinae
<i>Archicypraea</i>	SCHILDER, 1927	Simniini
<i>Gisortia</i>	SCHILDER, 1927	Gisortiinae
<i>Bernaya</i>	SCHILDER, 1927	Bernayini
<i>Cypraeorbis</i>	SCHILDER, 1927	Cypraeorbini
<i>Erronea</i>	SCHILDER, 1927	Erroneini
<i>Jenneria</i>	THIELE, 1929	Jenneriinae
<i>Amphiperas</i>	WINCKWORTH, 1929	Amphiperatidae
<i>Cypraeacites</i>	SCHILDER, 1930	Cypraeacitinae
<i>Volva</i>	SCHILDER, 1932 a	Volvini
<i>Luria</i>	SCHILDER, 1932 b	Luriini
<i>Pustularia</i>	SCHILDER, 1932 b	Pustulariini
<i>Naria</i>	SCHILDER, 1932 b	Nariinae
<i>Zonaria</i>	SCHILDER, 1932 b	Zonariini
<i>Umbilia</i>	SCHILDER, 1932 b	Umbiliini
<i>Cyproglobina</i>	SCHILDER, 1932 b	Cyproglobinini
<i>Sulcocypraca</i>	SCHILDER, 1932 b	Sulcocypraeini
<i>Zoila</i>	IREDALE, 1935	Zoilinae
<i>Staphylaea</i>	IREDALE, 1935	Staphylaeinae
<i>Austrocypraea</i>	IREDALE, 1935	Austrocypraeinae
<i>Eratotrivia</i>	SCHILDER, 1936	Eratotriviini
<i>Pusula</i>	SCHILDER, 1936	Pusulini
<i>Conocypraea</i>	SCHILDER, 1936	Conocypraeini
<i>Mandolina</i>	SCHILDER, 1936	Mandolinini
<i>Talparia</i>	SCHILDER, 1936	Talpariini
<i>Johnstrupia</i>	SCHILDER, 1939	Johnstrupiini
<i>Triviella</i>	SCHILDER, 1939	Triviellini
<i>Pseudocypraea</i>	STEADMAN & COTTON, 1943	"Subfamily <i>Pseudocypraea</i> "
<i>Adusta</i>	STEADMAN & COTTON, 1946	Adustinae
<i>Mauritia</i>	STEADMAN & COTTON, 1946	Mauritiinae

were based on the erroneous assumption that the oldest generic name must be used for the designation of the higher taxon (see Art. 64).  
(see Table 2, page 33)

It is rather difficult to construct a dichotomous key to the taxa of this family group, as they represent members of the phylogenetic tree gradually passing each into the other and terminal branches often showing parallel devel-

Table 2

SUPERFAMILY	FAMILY	Subfamily	Tribus (Infrafamily)
TRIVIACEA	TRIVIIDAE <sup>1</sup>	Eratoinae	† Johnstrupiini
TRIVIACEA	TRIVIIDAE	Eratoinae	Eratoini
TRIVIACEA	TRIVIIDAE	Eratoinae	† Eratotriiviini
TRIVIACEA	TRIVIIDAE	Triviinae	Triviellini
TRIVIACEA	TRIVIIDAE	Triviinae	Triviini
TRIVIACEA	TRIVIIDAE	Triviinae	Pusulini
TRIVIACEA	PEDICULARIIDAE		
CYPRAEACEA	CYPRAEIDAE <sup>2</sup>	Bernayinae <sup>3</sup>	† Archicypraeini <sup>4</sup>
CYPRAEACEA	CYPRAEIDAE	Bernayinae	Bernayini <sup>5</sup>
CYPRAEACEA	CYPRAEIDAE	Bernayinae	† Gisortini
CYPRAEACEA	CYPRAEIDAE	Cypraeinae	Cypraeini <sup>6</sup>
CYPRAEACEA	CYPRAEIDAE	Cypraeinae	Luriini
CYPRAEACEA	CYPRAEIDAE	Erroneinae <sup>7</sup>	Zonariini
CYPRAEACEA	CYPRAEIDAE	Erroneinae	Cypraeovulini <sup>8</sup>
CYPRAEACEA	CYPRAEIDAE	Erroneinae	Erroneini <sup>9</sup>
CYPRAEACEA	CYPRAEIDAE	Erosariinae <sup>10</sup>	Pustulariini <sup>11</sup>
CYPRAEACEA	CYPRAEIDAE	Erosariinae	Erosariini <sup>12</sup>
CYPRAEACEA	OVULIDAE <sup>13</sup>	Eocypraeinae <sup>14</sup>	Eocypraeini <sup>15</sup>
CYPRAEACEA	OVULIDAE	Eocypraeinae	Jenneriini <sup>16</sup>
CYPRAEACEA	OVULIDAE	Eocypraeinae	† Cypraediini
CYPRAEACEA	OVULIDAE	Ovulinae <sup>17</sup>	Ovulini <sup>18</sup>
CYPRAEACEA	OVULIDAE	Ovulinae	Simniini <sup>19</sup>

## Synonyms:

<sup>1</sup> Eratoidae<sup>2</sup> Porcellanidae<sup>3</sup> Cypraeorbinae, Zoilinae<sup>4</sup> Mandolinini<sup>5</sup> Cypraeorbini, Zoilini<sup>6</sup> Talpariini, Mauritiini<sup>13</sup> Amphiperasidae, Amphiperatidae<sup>7</sup> Cypraeovulinae<sup>8</sup> Umbilini<sup>9</sup> Adustini<sup>10</sup> Cypraeacitinae, Nariinae<sup>11</sup> Cypraeacitini, Austrocypraeini, Conocypraeini<sup>12</sup> Nariini, Staphylaeini<sup>14</sup> Jenneriinae, Sulcocypraeinae<sup>15</sup> Sulcocypraeini, Pseudocypraeini<sup>16</sup> Cyproglobinini<sup>17</sup> Amphiperatinae<sup>18</sup> Amphiperatini<sup>19</sup> Volvini

opment of characters. Therefore there are many species and even genera which do not fit the most outstanding characters of a higher taxon, although the sum of all other characters points to close relationship to this taxon. Nevertheless, the taxa of the family groups belonging to the superfamilies Triviacea and Cypraeacea roughly may be distinguished as follows (see also SCHILDER, 1936 and 1939):

## DICHOTOMOUS KEY

(R = radula; S = shell)

- 1 Osphradium semilunar, pedal ganglia short, echinospira well developed Triviacea ..... 2  
 - Osphradium trifold, pedal ganglia long, echinospira

- wanting Cypraeacea ..... 8  
 2 Vagile, siphon distinct, R: laterals dagger-like, S: outer lip denticulate Triviidae ..... 3  
 - Sessile, siphon obsolete, R: laterals trifid, S: cuplike ..... Pediculariidae  
 3 Siphon separated by a rim, S: anterior margin of the fossula free Eratoinae ..... 4  
 - Siphon not separated if extended, S: fossula connected with the dorsal wall in front Triviinae .. 6  
 4 S: dorsum smooth or granulate, fossula smooth or reduced ..... 5  
 - S: dorsum and fossula transversely ribbed ..... † Eratotriiviini  
 5 S: fossula reduced, anterior columellar teeth coarse, transverse ..... † Johnstrupiini

- S: fossula well developed, smooth (rarely denticulate within) ..... Eratoini
- 6 S: aperture wide, outer lip narrow, terminal teeth projecting ..... Triviellini
- S: aperture narrow, central, outer lip broader, terminal teeth hardly separable ..... 7
- 7 S: dorsum smooth between the ribs .... Triviini
- S: dorsum finely granulate between the ribs Pusulini
- 8 Osphradium central, large, R: laterals with coarse cusps, S: spire never involute Cypraeidae 9
- Osphradium displaced to the front, small, R: laterals flabellate, S: spire involute so that the cast shows a hole behind Ovulidae ..... 18
- 9 R: median without basal lamella, S: margins never pitted, anterior columellar teeth short, dorsum mostly freckled with brown, with several bands 10
- R: median mostly with a basal lamella, S: margins mostly pitted, anterior columellar teeth transversely extended, dorsum with white spots, with one band only Erosariinae ..... 17
- 10 S: spire mostly projecting, shell medium size to large, barely margined ..... 11
- S: spire mostly umbilicate, shell small to medium size, outer lip margined Erroneinae ..... 15
- 11 S: fossula smooth, never denticulate within, spire mostly broad Bernayinae ..... 12
- S: fossula transversely ribbed or denticulate within, spire less broad Cypraeinae ..... 14
- 12 S: medium size to large, without appendices, teeth and fossula distinct ..... 13
- S: large to gigantic, with large appendices, teeth and fossula obsolete, spire extremely broad ..... † Gisortiini
- 13 S: elongate, fossula rather reduced to absent ..... † Archicypraeini
- S: globular, fossula broadly concave .. Bernayini
- 14 R: laterals large, median smaller, S: with four bands ..... Cypraeini
- R: laterals reduced, median very large, S: trizonate ..... Luriini
- 15 S: spire slightly projecting, fossula broad Zonariini
- S: spire mostly umbilicate, fossula narrow to obsolete ..... 16
- 16 S: fossula reduced to obsolete .... Cypracovulini
- S: fossula distinct though narrow, bituberculate ..... Erroneini
- 17 S: fossula rather broad but inner denticles obsolete, pittings obsolete ..... Pustulariini
- S: fossula narrow, but inner denticles mostly coarse, pittings mostly distinct ..... Erosariini
- 18 R: laterals narrow, with few flabella; S: columellar teeth distinct Eocypraeinae ..... 19
- R: laterals triangular with many flabella, S: columellar teeth absent Ovulinae ..... 21
- 19 S: fossula broad, smooth ..... 20
- S: fossula reduced, shell covered with fine spiral ribs ..... Cypraeidiini
- 20 S: pyriform, dorsum smooth, rarely with fine ribs ..... Eocypraeini
- S: ovate to elongate, dorsum often ribbed or pustulate ..... Jenneriini
- 21 S: pyriform, labial teeth and terminal ridge distinct ..... Ovulini
- S: fusiform, labial teeth and terminal ridge obsolete ..... Simniini

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## The Range of *Trivia myrae* CAMPBELL

BY

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(1 Map)

A NEW MEMBER of Triviidae, *Trivia myrae*, was described by CAMPBELL (1961), who referred it to the subgenus *Pusula*. The type locality is the channel between Loreto, Baja California and Carmen Island, which lies between 5 and 10 miles offshore in the Gulf of California. The holotype and two paratypes were trawled in this locality, while seven additional specimens were trawled off Monserrate Island, Gulf of California, and two specimens were dredged off Punta Final, Baja California. It was further stated that extensive dredging at the mainland locations of Puerto Peñasco, Guaymas, Mazatlán, Salina Cruz, and El Salvador failed to produce additional specimens. The conclusion was accordingly reached that this species appeared to be limited to the eastern (*i. e.* Gulf of California) shore of Baja California.

*Trivia myrae* does not appear in a checklist of mollusks for Puertecitos (DUSHANE, 1962). This locality is on the eastern shore of Baja California, about 45 miles north of Punta Final. It is noteworthy that the collectors who contributed information used in the compilation of this checklist include the author of the species.

EMERSON & OLD (1963) then reported finding three specimens off Coronados Island and one specimen off

Puerto Escondido, and although the latter was stated to represent an extension of the range southward, Puerto Escondido is in fact *north* of Monserrate Island.

I wish to report a further range extension on the basis of two shells from Puerto Peñasco (*leg.* Nora Donohue). These were discovered in a large lot of beach *Trivia*, which consisted in the main of *T. solandri* (SOWERBY) and *T. californiana* (GRAY), collected in April, 1964. The two *T. myrae* in the lot were identified by F. A. Schilder, who referred to them (*in litt.*) as subspecific of *T. fusca* SOWERBY. There are, therefore, some taxonomic problems to be settled here, because *T. fusca* and *T. myrae* are, at present, assigned to different subgenera, viz., *Cleotrivia* IREDALE and *Pusula* JOUSSEAUME, respectively. The diagnostic difference between *Cleotrivia* and *Pusula* is, according to KEEN (1958), that in the former the rib ends in the dorsal furrow interrupting the ribs are not beaded, while in the latter the rib ends are beaded. The original description of *T. myrae* (CAMPBELL, 1961) states "as the ribs enter the dorsal sulcus, the color is lighter, giving the impression of very slight beading." The status of these two subgenera, it would seem, deserves further study.

In any case, the range extension of *T. myrae* to the mainland coast of the Gulf of California suggests that

<sup>1</sup> Contribution No. 286.



Map of the Gulf of California, showing the localities from which *Trivia myrae* has been reported.

this species should be sought at other mainland locations, especially in the states of Sonora and Sinaloa.

All of the localities mentioned in the above note, with the exception of Salina Cruz and El Salvador, which are far to the south of the others, are shown in Figure 1, which was drawn by Mrs. Maryellin Reinecke.

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## The Terebridae of Fiji

(Mollusca : Gastropoda)

BY

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(Plates 4 to 7; 13 Text figures)

THIS FAUNAL STUDY is the fifth in the series of faunal monographs on the mollusks of Fiji. Records were based on specimens collected by resident collectors and the authors, by methods of hand-collecting and boat dredging to a depth of 20 fathoms.

The recent faunal list of Terebridae published by J. CATE & R. D. BURCH (1964) proved to be of great assistance in the elucidation of Fijian terebrid material, since all Fiji records in this list were based exclusively on the junior author's collection; thus all previous identifications could be confirmed and verified.

The majority of Terebridae have an Indo-West Pacific distribution, ranging from the Red Sea region to Polynesia and the Hawaiian Islands; there are no species endemic to the Fiji Islands.

Notes on the geography of the Fiji Islands and other pertinent data have been given in a previous publication (CERNOHORSKY, 1964).

### HABITAT AND VARIATION

Members of the family Terebridae are primarily sand-dwellers; they inhabit clean, muddy or silty sand substrates, and occasionally are dredged on substrates consisting of broken coral and sand. Certain species prefer a habitat of clean sand thickly interspersed with weed. Terebridae are both diurnal and nocturnal and display great activity a few minutes after the turn of the tide, similar to members of the families Mitridae, Volutidae and Naticidae. This activity rhythm is constant and persistent in species inhabiting sand-patches of the intertidal zone, and the track-

movement is generally directed towards the incoming tide. The activity rhythm of the Terebridae is timed to coincide with the ceasing of water-agitation with the receding tide and recommencement on the rising tide. Sand-patches on reefs where wave-action is violent are generally barren of Terebridae; sandy stretches surrounding sheltered beaches and bays of outer islands are the most prolific hunting grounds of terebrids, especially the larger species. The amplitude of oxygen-saturation at low tide may have a direct bearing on the peak activity of Terebridae at this time.

Marine Mollusca, and Terebridae are no exception, are generally subject to a much greater variation in relation to environment and other factors than would be realized by workers whose experience lies only with museum collections. In cases where varietal names have been assigned to forms which are undoubtedly the result of direct influence of environment, these have been dismissed as useless synonyms; only with a few exceptions are such varieties restricted in geographical range and may validly be regarded as geographical races or subspecies. The range of variation, diverse as it may be, is by no means infinite, and the majority of specimens from a restricted geographical region will generally fall within the established range of variability.

### THE ANIMAL

The structure of the animal is that of a typical gastropod, that is, it consists of a body and foot, mantle, siphon, tentacles, eyes, proboscis, poison apparatus, sexual and vegetative organs, and an operculum.

The foot is moderately small in relation to shell-length but powerfully muscular and cleaved anteriorly; in shape it is bluntly truncated anteriorly and pointedly rounded posteriorly.

The proboscis is generally very large and invertible in *Terebra s. str.* Examination of almost forty specimens of the more common species of *Terebra* failed to disclose a radular ribbon. The food is most probably conveyed directly to the gut by the invertible proboscis. The function of the poison gland in Terebridae, however, is less clear.

The eyes are small and situated on the tips of very small eye-stalks; in some species the eyes are attached to the stalks a short distance below the summits.

The penis is generally "scimitar-shaped" and from 15% to 30% of the shell-length in size, hidden by the thin mantle cover and facing backwards.

The operculum is either broad and oval or slender and elliptical and is of great diagnostic assistance in the separation of living forms of Terebridae.

### GENERA OF TEREBRIDAE

Numerous generic and subgeneric names have been proposed from time to time for assemblages of species of Terebridae. Species of terebrids have been placed in the genus *Buccinum* by LINNAEUS (1758), *Epitonium* by RÖDING (1798), *Terebra* by LAMARCK (1799), and *Vertagus* by LINK (1807). BRUGUIÈRE (1789, p. 15), who established the genus *Terebra*, failed to include any nominal species in his new genus. LAMARCK (1799) listed *Terebra subulata* (LINNAEUS) as the only species of BRUGUIÈRE's genus, and this species becomes the type-species of *Terebra* BRUGUIÈRE by subsequent monotypy. H. & A. ADAMS (1853 to 1858) combined all known Terebrid species under the familial name Terebridae and established the genus *Hastula*. DALL (1908) and BARTSCH (1923) subdivided the family into various sections and established subdivisions of the family, some of which are used as subgenera by recent authors. OYAMA (1961, 1961 a) added several taxonomic units to the family besides having re-organized the group. KURODA & HABE (1952) accept a division of four genera in the family Terebridae, i. e. *Terebra* BRUGUIÈRE, 1789, *Hastula* H. & A. ADAMS, 1853, *Diplomeriza* DALL, 1919 (= *Duplicaria* DALL, 1909) and *Terenolla* IREDALE, 1929. We have on anatomical grounds followed this arrangement with only minor additions.

The genus *Terebra s. str.* is characterized by the absence of a radular ribbon. *Duplicaria* has a radular ribbon consisting of two curved teeth per row, with additional

denticles which are absent in *Hastula*. The genus *Hastula* has a radula of some two dozen rows of slender curved teeth. The radular teeth of *Impages* E. A. SMITH, 1873 (vide THIELE, 1931) are appreciably different from those of *Hastula*, so that *Impages* had to be retained as a full genus for the species *I. hectica* (LINNAEUS).

Subgenera of Terebridae have often been based on single conchological characters, mostly those of sculpture, e. g. the punctate subsutural groove separating *Hastula s. str.* from *Punctoterebra* BARTSCH, 1923, or the punctostriate grooves and cords separating *Dimidacus* IREDALE, 1929, from *Perirhoe* DALL, 1908. Consequently authors have assigned species to these various subgenera in an amazingly haphazard fashion. For subgeneric sections we have accepted the arrangement of recent writers (BURCH, 1964, 1965), with the exception of *Punctoterebra* BARTSCH and *Dimidacus* IREDALE, and we intend to leave the question of a more precise classification for future consideration. The existence of smooth and punctate forms of *Hastula penicillata* (HINDS), makes the validity of the subgenus *Punctoterebra* suspect.

### ACKNOWLEDGMENTS

We would like to acknowledge our gratitude to Mr. R. D. Burch for his assistance with our project. Mr. Burch has only recently worked with Fijian Terebridae, mainly those from the Jennings collection and had the opportunity to compare these with specimens of the species from neighbouring territories. His findings and opinions were freely made available to us with other information pertaining to Fijian Terebridae.

We offer our thanks to Mr. N. Tebble and Mr. S. P. Dance from the British Museum (Natural History) for photographs of E. A. Smith's holotypes; we also would like to record our appreciation to the Trustees of the British Museum for permission to reproduce these holotype photographs in this paper.

We are grateful to Dr. O. Paget, Naturhistorisches Museum, Vienna, for information concerning the holotype of *Buccinum candidum* BORN.

We have consulted several Fiji collections in search for new geographical records and specific variants. We would like to thank the following collectors for the opportunity of having their collections made available to us: Mr. and Mrs. P. Bean, Ba; Mr. and Mrs. R. Browne, Nausori; Mr. J. Farkas, Vatukoula; Mr. and Mrs. Freitag, Suva; Mrs. J. Hill, Suva; Mr. and Mrs. W. Erich, Deuba; Mr. and Mrs. R. Gell, Suva; Mr. and Mrs. Miller, Tailevu; Mr. K. Mijts, Lautoka; and Mr. and Mrs. I. Morse, Lautoka.

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## DESCRIPTION OF SPECIES

Toxoglossa TROSCHEL, 1848

TEREBRIDAE H. & A. ADAMS, 1853

*Terebra* BRUGUIÈRE, 1789

Type species: *Buccinum subulatum* LINNAEUS, 1767  
= *Terebra subulata* (LINNAEUS, 1767)

*Terebra* s. str.

1. *Terebra* (*Terebra*) *guttata* (RÖDING, 1798)

(Plate 4, Figure 5)

1758. *Buccinum maculatum* LINNAEUS, (pars), Syst. Nat. ed. 10, p. 741, no. 415 (RUMPHIUS, 1705, pl. 30, fig. D)  
1767. *Buccinum subulatum* LINNAEUS (pars), Syst. Nat., ed. 12, p. 1205, no. 480 (SEBA, 1758, pl. 56, fig. 11)  
1798. *Epitonium guttatum* RÖDING, Mus. Bolten., p. 94  
1817. *Buccinum oculatum* DILLWYN, Descr. cat. rec. shells, 2: 642  
1845. *Buccinum ornatum* "MARTYN," CHENU, Univ. Conch. p. 25, pl. 33, fig. 1  
1858. *Terebra nebulosa* LOROIS, Journ. Conchyl. 7: 90, pl. 1, fig. 4 (non SOWERBY, 1825; nec KIENER, 1839)  
1859. *Terebra laroisi* DESHAYES, Proc. Zool. Soc. London, p. 313, no. 211 (nom. nov. pro *T. nebulosa* LOROIS, 1858)  
1869. *Terebra sculptilis* PEASE, Amer. Journ. Conch. 5: 65  
1915. *Epitonium guttatum* DALL, Ind. Mus. Bolten., p. 30 (valid emendation)

**Shell:** Shell large and slender; orange to orange-brown in colour, rarely dark fawn, ornamented with two rows of large round white and slightly elevated spots. Whorls flattened, slightly convexly rounded at sutures, numbering about 21 apart from protoconch. Body whorl with two rows of large white convex spots, ultimate row disappearing into the white or flesh-coloured aperture; numerous but faint finely punctate lines encircle the body whorl, and additional growth-marks make the shell appear grooved. Columella white, flat, with a raised cord on the outer margin; anterior canal straight.

**Size:** 65 to 130 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - From the Red Sea through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** *Buccinum candidum* BORN, 1780, is possibly identical with this species. BORN's holotype, which is preserved in the Vienna Natural History Museum, has been labelled *Terebra oculata* LAMARCK (Dr. Paget, in litt.).

2. *Terebra* (*Terebra*) *subulata* (LINNAEUS, 1767)

(Plate 4, Figure 2)

1758. *Buccinum maculatum* LINNAEUS (pars), Syst. Nat., ed. 10, p. 741, no. 415 (RUMPHIUS, 1705, pl. 30, fig. B; GUALTIERI, 1742, pl. 56, fig. B)  
1767. *Buccinum subulatum* LINNAEUS (pars), Syst. Nat., ed. 12, p. 1205, no. 480  
1810. *Terebrum tigreum* MONTFORT, Conch. Syst., 2: 430, fig. 2  
1811. *Terebra fusca* PERRY, Conchology, 5, pl. 16, fig. 3 (non DAUTZENBERG, 1935)  
1845. *Buccinum varium* "MARTYN," CHENU, Univ. Conch., p. 26, pl. 33, fig. 2a  
1859. *Terebra tigrina* CHENU, Man. Conch., 1: 219, fig. 1207 (non *Buccinum tigrinum* GMELIN, 1791)  
1921. *Terebra taurina* DALL, Nautilus, 34: 125 (non *Buccinum taurinum* SOLANDER in LIGHTFOOT, 1786)

**Shell:** Shell large, slender and smooth; cream to fawn in colour, rarely pale brown, ornamented with two rows of squarish or rectangular, often equal sized, dark brown blotches on whorls. Whorls flat, convexly rounded at sutures, numbering about 18 apart from protoconch; early whorls axially plicate. A spiral groove is situated anteriorly from the sutures; groove prominent on early whorls but often obsolete on later whorls. Body whorl with 3 rows of dark brown blotches, ultimate row disappearing into the white or pale fawn aperture; columella white, centrally undulate and plicate; anterior canal recurved.

Juvenile specimens have somewhat concave whorls with faint axially curved growth lines and spiral lines and a distinct presutural fasciole; sutures crenulate, early whorls plicate. Colour pattern is complete, with the brown blotches extending over the sutures.

**Size:** 35 to 168 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Moderately common.



Figure 1

Operculum of *Terebra subulata* (LINNAEUS)

**Distribution:** Throughout the Fiji Islands. – From the Red Sea through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** *Terebra achates* WEAVER, 1960, a species endemic to the Hawaiian Islands, is superficially similar but differs mainly in having whorls sculptured with from four to seven punctate spirals which are intersected by axially curved obsolete axials in the form of growth striae.

(*Oxymoris*) DALL, 1908

**Type species:** *Buccinum maculatum* LINNAEUS, 1758  
= *Terebra maculata* (LINNAEUS, 1758).

### 3. *Terebra (Oxymoris) chlorata* LAMARCK, 1822

(Plate 4, Figure 8)

1822. *Terebra chlorata* LAMARCK, Anim. sans Vert. 7: 288

1834. *Terebra knorri* GRAY, Proc. Zool. Soc. London, p. 59

**Shell:** Shell moderate in size, moderately heavy and ventricose, smooth; ivory-white in colour, ornamented with irregular violet-brown blotches on the presutural band and another row of blotches on the whorl; the latter are connected to the sutures by irregular wavy lines. Whorls flat and smooth, numbering about 14 apart from protoconch; early whorls obsoletely plicate. Presutural band defined by a moderately deep spiral groove. Body whorl with two rows of violet-brown blotches, followed by a narrow interrupted peripheral band and an ultimate band of brown blotches which enter the aperture. Columella white, straight, plicate, and with a prominent rounded cord; interior of aperture whitish.

**Size:** 55 to 85 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Moderately uncommon.

**Distribution:** Throughout the Fiji Islands. – From East Africa through the tropical Indo-Pacific to Polynesia and Hawaii.

### 4. *Terebra (Oxymoris) crenulata* (LINNAEUS, 1758)

(Plate 4, Figures 6, 6a)

1758. *Buccinum crenulatum* LINNAEUS (pars), Syst. Nat., ed. 10, p. 741, no. 416 [(ARGENVILLE, 1742, pl. 14, fig. Y and GUALTIERI, 1742, pl. 57, fig. L only) – non BRUGUIÈRE, 1789 = *Nassa* sp.]

1767. *Buccinum hecticum* LINNAEUS (pars), Syst. Nat., ed. 12, p. 1206, no. 482 [(non LINNAEUS, 1758) – SEBA, 1758, pl. 56, fig. 21 only]

1791. *Buccinum varicosum* GMELIN, Syst. Nat., ed. 13, p. 3505

1811. *Terebra maculata* PERRY, Conchology 5, pl. 16, fig. 2 (non *Buccinum maculatum* LINNAEUS, 1758)

1845. *Buccinum luteolum* "MARTYN," CHENU, Univ. Conch., p. 25, pl. 33, fig. 1a (smooth form)

1857. *Terebra fimbriata* DESHAYES, Journ. Conchyl., 6: 71, pl. 5, fig. 1 (smooth form)

1859. *Terebra interlineata* DESHAYES, Proc. Zool. Soc. London, p. 277, no. 8

1893. *Terebra crenulata* var. *booleyi* MELVILL & SYKES, Proc. Malac. Soc. London 3 (1): 42, pl. 3, fig. 5

**Shell:** Shell large, moderately heavy and evenly tapered; flesh-pink in colour, rarely pale fawn, ornamented with darker patches of flesh colour. Whorls with two equidistant rows of small evenly spaced brown dots. Whorls flat, numbering about 15 apart from protoconch of 3 nuclear whorls; early whorls axially plicate. Sutures with a series of prominent pointed white crenulations which at times become obsolete. Body whorl with 3 rows of evenly spaced brown dots, ultimate row disappearing into the pale flesh aperture. Columella pale flesh in colour, calloused, with a white ridge on the margins; raised undulating ridges cross columella, anterior canal straight.

Juvenile shells have prominent axial ribs on whorls, a punctate presutural spiral groove is evident and sutures are closely packed with nodules; the colour pattern is otherwise complete.

**Animal:** Foot light fawn, siphon creamy-white to pale flesh in colour; eyes black, situated on top of short creamy coloured eye stalks measuring about 5 mm in length.

**Size:** 15 to 120 mm.

**Habitat:** In clean sand, from 0 - 3 fathoms.

Moderately common.

**Distribution:** Throughout the Fiji Islands. – From the Red Sea through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** The species generally prefers sheltered areas with clean sand. Specimens from shore reefs are generally darker in colour than those from offshore areas.

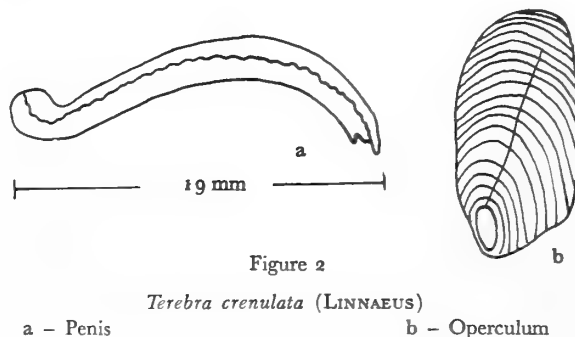


Figure 2

*Terebra crenulata* (LINNAEUS)

a – Penis

b – Operculum

A smooth form of *Terebra crenulata* occurs sporadically in all populations, and is not restricted to a certain geographical area. This individual variant has been described as *T. fimbriata* DESHAYES, 1857.

*Terebra interlineata* DESHAYES appears to be a variant with prominent and numerous axial ribs.

### 5. *Terebra (Oxymoris) felina* (DILLWYN, 1817)

(Plate 4, Figure 9)

1791. *Buccinum tigrinum* GMELIN, Syst. Nat., ed. 13, p. 3502 (non GMELIN, 1791, p. 3475)

1817. *Buccinum felinum* DILLWYN, Descr. cat. rec. shells, 2: 644, no. 135

1869. *Terebra suffusa* PEASE, Amer. Journ. Conch., 5:65

**Shell:** Shell moderate in size, slightly ventricose and smooth; silky-white, ornamented with a spiral row of brown spots on whorls posteriorly to sutures. Whorls smooth and flat, numbering 11 to 14 apart from protoconch of 2 nuclear whorls; presutural band broad, defined by a shallow spiral groove, becoming deeper and punctate on early whorls which are axially plicate. Body whorl with two rows of brown spots and obsolete spiral striae; columella white and straight, centrally ridged, interior of aperture white.

**Size:** 40 to 87 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - From East Africa through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** In the majority of Hawaiian specimens the brown spots are almost obsolete (*fide* WEAVER, 1960), which is not the case in Fiji specimens.

### 6. *Terebra (Oxymoris) maculata* (LINNAEUS, 1758)

(Plate 4, Figure 1)

1758. *Buccinum maculatum* LINNAEUS (pars), Syst. Nat., ed. 10, p. 741, no. 415

1840. *Terebra maculosa* PFEIFFER, Krit. Reg. Conch. Cab., p. 41

1935. *Terebra (Subula) maculata* var. *confluens* DAUTZENBERG, Mém. Mus. Hist. Nat. Belg., 17 (2): 31

**Shell:** Shell large, broad and heavy; white or cream in colour, ornamented with two rows of axially oriented dark brown blotches on whorls; blotches anterior to the suture generally larger, occasionally merging to form large patches. Whorls smooth and flat, numbering about 19 apart from protoconch; early whorls axially plicate, last whorl with two rows of dark brown blotches, followed by

three rows of light brown or dark fawn squarish spots. Columella white, strongly plicate; aperture white, anterior canal straight.

Juvenile shells, 15 to 20 mm in length, have a completed colour pattern; whorls have a prominent subsutural groove, oblique axial ribs and coarsely crenulate sutures. Whorls number 10 apart from  $2\frac{1}{2}$  glassy-white nuclear whorls; last whorl is axially plicate, ornamented with two pale whitish spiral bands.

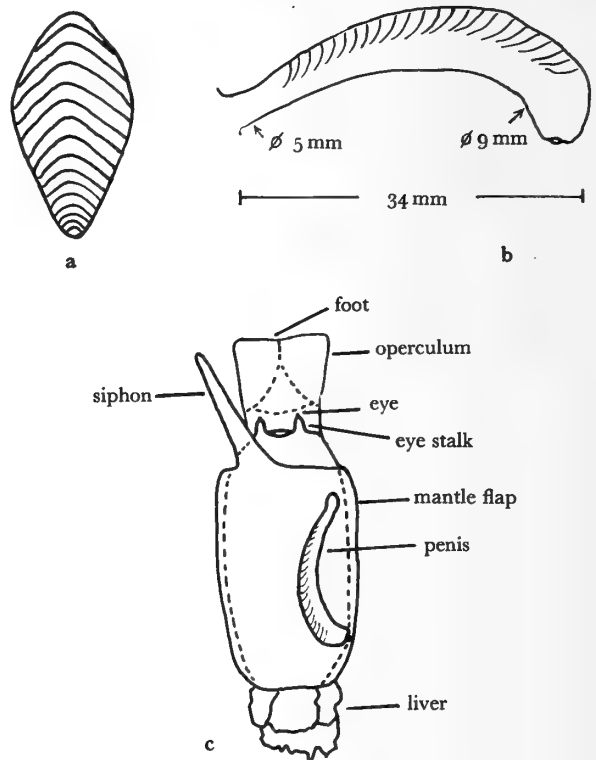


Figure 3

*Terebra maculata* (LINNAEUS)

a - Operculum                      b - Penis  
c - Lateral view of anterior portion of animal

**Animal:** Sole and dorsum of foot light fawn, siphon creamy-white, eye-stalks light fawn, 4 - 6 mm in length and 2 - 3 mm in width; eyes greyish-black, situated on tips of eye-stalks, diameter of pupil 0.2 mm. Proboscis large, light yellow in colour and about 73 mm long and 11 mm wide, with a series of transverse annular muscles. Penis "scimitar-shaped" but rounded at distal end, smooth

on one side and with a series of ripples on the other.

**Size:** 15 to 200 mm

**Habitat:** In clean sand, from 0 - 5 fathoms.

Common.

**Distribution:** Throughout the Fiji Islands. – From the Red Sea through the tropical Indo-Pacific to Polynesia and Hawaii.

(*Subula*) SCHUMACHER, 1817

**Type species:** *Buccinum dimidiatum* LINNAEUS, 1758

= *Terebra dimidiata* (LINNAEUS, 1758)

### 7. *Terebra (Subula) areolata* (LINK, 1807)

(Plate 4, Figure 3)

1758. *Buccinum dimidiatum* LINNAEUS (pars), Syst. Nat., ed. 10, p. 742, no. 420 (SEBA, 1758, pl. 56, figs. 23, 24, 27)

1767. *Buccinum subulatum* LINNAEUS (pars), Syst. Nat., ed. 12, p. 1205, no. 480 (SEBA, 1758, pl. 56, fig. 16)

1807. *Vertagus areolatus* LINK, Besch. Nat.-Samml. Univ. Rostock, p. 128 (CHEMNITZ, 1780, pl. 154, fig. 1443)

1816. *Terebra subulata* LAMARCK, Tabl. Encycl. Méth., p. 3, pl. 402, figs. 2 a, 2 b (non *Buccinum subulatum* LINNAEUS, 1767)

1817. *Buccinum maculatum* var. DILLWYN, Descr. cat. rec. shells 2: 642 (non LINNAEUS, 1758)

**Shell:** Shell large and slender, slightly broadening towards body whorl; cream to fawn in colour, ornamented with three rows of blackish-brown squarish blotches on whorls, those posterior to the suture being the largest. Whorls flat, numbering about 20 apart from protoconch of two nuclear whorls; early whorls axially plicate. A presutural ledge is evident, giving the whorls a divided and slightly step-like appearance. Body whorl with four rows of evenly spaced squarish blotches, ultimate row disappearing into the pale fawn aperture; faint, extremely fine punctate spiral lines are superimposed over the pattern. Columella pale fawn, thin, with a high and rounded margin, anterior canal straight.

**Size:** 40 to 130 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Moderately common.

**Distribution:** Throughout the Fiji Islands. – From East Africa through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** The species superficially resembles *Terebra subulata* (LINNAEUS); the latter has shorter undivided whorls, which are roundly angulate at the sutures. There are only two rows of almost equal sized blotches on the whorls, and three rows on the body whorl.

### 8. *Terebra (Subula) argus argus* HINDS, 1844

(Plate 4, Figure 7)

1822. *Terebra muscaria* LAMARCK, Anim. sans Vert., 7: 285

1839. *Terebra nebulosa* KIENER, Spéc. Gen. Icon. Coq. Viv., p. 23, pl. 10, fig. 21 (non SOWERBY, 1825)

1844. *Terebra argus* HINDS, Proc. Zool. Soc. London, for 1843: 160

**Shell:** Shell moderate in size, slender and slightly broadening towards the body whorl; whitish to creamy-white in colour, ornamented with three rows of nebulous, yellow squarish spots; one row of spots is situated on the presutural band and two rows on the whorl. Whorls smooth, flat, only slightly rounded at sutures, numbering about 16 apart from protoconch; early whorls axially plicate, plicae becoming obsolete on the last two or three whorls. The presutural band is defined by a deeply punctate spiral groove. Body whorl with four rows of spots, ultimate row disappearing into the pale fawn aperture. Columella whitish, outer margin extended to form a sharp calloused area; anterior canal straight.

**Size:** 50 to 85 mm.

**Habitat:** In slightly muddy and silty sand, in shallow water.

Rare.

**Distribution:** South and West Viti Levu. – From the Philippine Islands through the tropical Pacific to Polynesia and Hawaii.

**Discussion:** *Terebra argus brachygyra* PILSBRY, 1921, which is endemic to the Hawaiian Islands, differs from the nominal species by having somewhat shorter whorls, deeper and crenulate sutures and distinct axial ribs.

### 9. *Terebra (Subula) dimidiata* (LINNAEUS, 1758)

(Plate 4, Figures 4, 4a)

1758. *Buccinum dimidiatum* LINNAEUS (pars), Syst. Nat., ed. 10, p. 742, no. 420 (SEBA, 1758, pl. 59, fig. 19 only)

1811. *Terebra carnea* PERRY, Conchology, 5, pl. 16, fig. 1

1845. *Buccinum vittatum* "MARTYN," CHENU, Univ. Conch., p. 26, pl. 88, fig. 2 (non LINNAEUS, 1767)

1857. *Terebra splendens* DESHAYES, Journ. Conchyl., 6: 73, pl. 5, fig. 11

1902. *Terebra chlorata* MARTENS, Rumph. Ged., p. 120 (non LAMARCK, 1822)

1935. *Terebra (Subula) dimidiata* var. *circumvoluta* DAUTZENBERG, Mém. Mus. Hist. Nat. Belg. 2 (17): 22, pl. 1, fig. 4

1935. *Terebra (Subula) dimidiata* var. *pallida* DAUTZENBERG, Mém. Mus. Hist. Nat. Belg. 2 (17): p. 23 (non DESHAYES, 1857)

**Shell:** Shell large and smooth; light orange to orange-red in colour, ornamented with irregular, often "Y"-shaped white lines and streaks. Whorls smooth, flat and shining,

numbering about 20 apart from protoconch; early whorls longitudinally plicate. Presutural band defined by a prominent spiral groove. Body whorl with two narrow white bands and wavy axial streaks; faint punctate lines encircle the body whorl and generally exceed 18 in number. Columella white with a raised rounded cord on the outer margin; anterior canal straight.

Juvenile shells are axially ribbed, presutural groove is deeply punctate and the sutures are crenulate; the colour pattern is complete.

**Animal:** The foot is light chestnut-brown, siphon creamy-white, eye-stalks light chestnut brown, eyes black.

**Size:** 20 to 125 mm.

**Habitat:** In clean and muddy sand, from 0 to 10 fathoms. Common.

**Distribution:** Throughout the Fiji Islands. – From East Africa through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** Specimens collected on shore reefs are generally darker in colour than those taken from offshore areas.

The description of *Buccinum dimidiatum* LINNAEUS in the 10th edition of the "Systema Naturae" (1758) contains five words which could be applied to several species, and no figure had been cited. In the 12th edition of the same work the description was repeated and five figures from SEBA were cited (1758, pl. 56, figs. 16, 19, 23, 24, 27); four of these figures represent *Terebra areolata* (LINK), while only figure 19 is a questionable representation of the *T. dimidiata* of DILLWYN (1817) and of subsequent authors. Figure 15 on the same plate in SEBA (*op. cit.*) is a good illustration for the *T. dimidiata* of authors, yet had not been cited by LINNAEUS. We are faced with a five-word description in both editions of the "Systema Naturae," four figures cited which represent *T. areolata*, while only one cited figure could possibly refer to *T. dimidiata*. The non-citation of good figures of *T. dimidiata* of authors by LINNAEUS strongly suggests that the *T. dimidiata* of LINNAEUS was in fact the species *T. areolata* of (LINK).

DAUTZENBERG (1935) committed a curious error when describing *Terebra dimidiata* var. *pallida*, which he based on two figures in CHEMNITZ (1780, 4, pl. 154, figs. 1817, 1818). On page 31 (*op. cit.*) the same CHEMNITZ figures were placed in the synonymy of *T. muscaria* LAMARCK (= *T. areolata*). These figures are the "*Buccinum hecticum linnaei*" of CHEMNITZ and represent the *T. dimidiata* of authors, not *T. areolata* (LINK).

(*Abretiella*) BARTSCH, 1923

**Type species:** *Terebra cerithina* LAMARCK, 1822

# 10. *Terebra* (*Abretiella*) *cerithina* LAMARCK, 1822

(Plate 5, Figure 24)

1822. *Terebra cerithina* LAMARCK, Anim. sans Vert., 7: 288

1844. *Terebra pulchra* HINDS, Proc. Zool. Soc. London for 1843: 151 (juvenile)

1921. *Terebra spaldingi* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 308-309

**Shell:** Shell moderate in size, solid, slightly ventricose; flesh-pink or bluish-white in colour, ornamented with whitish or fawn coloured wavy axial lines and a fawn



Figure 4

Operculum of *Terebra cerithina* LAMARCK

spiral band on whorls. Whorls flat, numbering about 14 to 15 apart from protoconch of 3 nuclear whorls; axial ribs number about 23, but are generally obsolete on the last three whorls. Presutural band defined by a punctured spiral groove. Body whorl with two fawn transverse bands and a narrow fawn line placed in between. Columella pink-flesh in colour, straight, with a raised and calloused area which joins outer lip at periphery; aperture flesh-white.

Small and juvenile specimens are ventricose, creamy-white in colour, sculptured with numerous axial riblets on all whorls. The axial ribs are interrupted by a deep presutural groove, intercostal spaces faintly stained with fawn, but all other pattern is absent.

**Animal:** Foot is creamy-tan in colour, siphon creamy-white; eyes black, situated on summits of short creamy coloured eye-stalks.

**Size:** 17 to 70 mm.

**Habitat:** In clean, slightly muddy and silty sand, from 0 to 5 fathoms.

Moderately common.

**Distribution:** Throughout the Fiji Islands. – Western Pacific Ocean to Polynesia and Hawaii.



(*Decorihastula*) OYAMA, 1961

**Type species:** *Terebra affinis* GRAY, 1834

11. *Terebra* (*Decorihastula*) *affinis* GRAY, 1834

(Plate 5, Figure 26)

1832. *Terebra striata* QUOY & GAIMARD, Voy. Astrol., p. 468, pl. 36, figs. 23, 24 (non BASTEROT, 1825)

1834. *Terebra affinis* GRAY, Proc. Zool. Soc. London, p. 60

1839. *Terebra pertusa* KIENER (pars), Spéc. Gen. Coq. Viv., pl. 11, fig. 24b (non *Buccinum pertusum* BORN, 1780)

**Shell:** Shell moderately small, slender, solid and shiny; creamy-white in colour, ornamented with longitudinal bluish-brown blotches and almost obsolete narrow transverse bands. Whorls flat to slightly convex, numbering about 13 to 15, apart from protoconch of three nuclear whorls; whorls sculptured with closely-packed axially



Figure 5

Operculum of *Terebra affinis* GRAY

curved and slightly convex ribs which bisect the whitish presutural band at an angle; axial ribs numbering about 18 to 22 on the penultimate whorl. On the late whorls axial ribs are flat, and intercostal spaces contain about 8 punctured grooves; on the early whorls axial ribs become slightly wider spaced and interstices are sculptured with short transverse grooves. Presutural band defined by a punctured spiral groove; interstices of axial ribs stained with brown. Body whorl with a pale brown transverse band and a white peripheral band; region near the anterior canal light brown. Columella fawn in colour, straight, with a sharp cord joining the apertural lip; aperture creamy-white or light fawn.

**Animal:** Foot light creamy-tan in colour, siphon and eye-stalks white, eyes black; eye-stalks measure 0.9 mm to

1.3 mm in height, and eyes are situated on the summit of the eye-stalks.

**Size:** 15 to 60 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Common.

**Distribution:** Throughout the Fiji Islands. - From East Africa through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** Occasional specimens show faint and almost obsolete spiral cords on whorls.

12. *Terebra* (*Decorihastula*) *columellaris* HINDS, 1844

(Plate 5, Figure 28)

1844. *Terebra columellaris* HINDS, Proc. Zool. Soc. London for 1843: 151

1850. *Terebra areolata* ADAMS & REEVE, Voy. Samarang, p. 30, pt. 4, pl. 10, fig. 23 (non *Vertagus areolatus* LINK, 1807)

1869. *Terebra propinqua* PEASE, Amer. Journ. Conch., 5: 66

**Shell:** Shell small and moderately slender; whitish in colour, flecked with irregular orange blotches. Whorls flat to slightly convex, numbering from 15 to 17, apart from protoconch of 3 nuclear whorls; sculpture consisting of elevated curved and rounded axial ribs numbering from 18 to 26 on the penultimate whorl. Presutural band defined by a spiral groove separating the whorls from a single row of white beads at the sutures; intercostal spaces with 6 to 13 short and deep spiral grooves which occasionally extend onto the walls of the axial ribs. Body whorl axially plicate, with a white peripheral band generally bordered by a thin orange spiral line; ultimate half of body whorl spirally striate and orange-brown in colour. Columella yellowish-white or pale orange, straight, with a plicate fold interiorly and a thin cord on the exterior; aperture light orange-brown with a white median band.

**Size:** 18 to 43 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 3 fathoms.

Uncommon.

**Distribution:** South and West Viti Levu. - From the Philippine Islands through the tropical Pacific to Polynesia and Hawaii.

**Discussion:** *Terebra undulata* GRAY is similar to this species but differs in being more ventricose, fawn to pale brown in colour throughout and lacking the blotches and white peripheral band, besides having fewer axial ribs.

13. *Terebra (Decorihastula) conspersa* HINDS, 1844

(Plate 4, Figure 12)

1844. *Terebra conspersa* HINDS, Proc. Zool. Soc. London for 1843: 153

**Shell:** Shell moderately small, heavy, broadening towards the aperture; cream to light fawn in colour, ornamented with interrupted spiral bands of brown axial streaks which become obsolete in some specimens and may only be visible at the sutures. Whorls slightly convex, numbering from 13 to 15, apart from protoconch; presutural band defined by a punctate spiral groove. Whorls sculptured with fine curved axial ribs, numbering from 23 to 55 on the penultimate whorl; intercostal spaces with 4 to 7 spiral grooves which faintly override axial ribs. Body whorl axially plicate and spirally grooved, with a broad dark tan peripheral band which enters the aperture; columella streaked with cream and tan, centrally ribbed, corded and almost straight.

**Animal:** The foot and siphon are rose-coloured and finely veined with white; eyes black, situated on the summits of short creamy-fawn eye-stalks; proboscis thin and long (10 mm), distal end coloured grey.

**Size:** 14 to 45 mm.

**Habitat:** In clean sand, from 0 - 5 fathoms.

Moderately common.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands to Fiji.

**Discussion:** The species is very variable in colouring and density of axial ribs. In specimens where the interrupted



Figure 6

Operculum of *Terebra conspersa* HINDS

brown spiral bands are absent, the intercostal spaces at the sutures are stained a dark brown. Fine-ribbed variants of the species have more than twice as many axial ribs on the whorl than coarse-ribbed forms.

14. *Terebra (Decorihastula) flavofasciata* PILSBRY, 1921

(Plate 6, Figure 35)

1921. *Terebra flavofasciata* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 306

**Shell:** Shell small and moderately slender; white or dirty-white in colour, ornamented with a faint orange-brown narrow transverse line on whorls, presutural groove irregularly stained with orange-brown. Whorls slightly convex, numbering about 15, apart from protoconch of  $2\frac{1}{2}$  rose-coloured nuclear whorls; sculpture consists of elevated moderately curved and rounded strong axial ribs, numbering about 19 on the penultimate whorl. Presutural band defined by a moderately deep spiral groove, which appears as deep pits in the interstices; some of these pits are occasionally stained with orange-brown; intercostal spaces with 7 - 8 short and moderately deep spiral grooves. Body whorl axially plicate with a narrow orange peripheral line, ultimate third and occasional intercostal space stained light orange-brown; columella creamy-white, straight, with an angulate cord exteriorly.

**Animal:** Foot light creamy-fawn, siphon vivid red, eye-stalks small, eyes black and situated just beneath the tip of the stalks.

**Size:** 27 mm.

**Habitat:** Dredged from 15 fathoms on clean sand substrate.

**Distribution:** West off Viti Levu. – Hawaii, New Guinea.

**Discussion:** This species which previously has been reported as endemic to the Hawaiian Islands, appears to have a Pacific Ocean distribution. The species *Terebra pumilio* (E. A. SMITH, 1873) may possibly be the same species.

15. *Terebra (Decorihastula) kilburni* R. D. BURCH, 1965

(Plate 6, Figures 32, 32a)

1965. *Terebra (Decorihastula) kilburni* R. D. BURCH, The Veliger, 7 (4): 249 - 250; pl. 31, fig. 8

**Shell:** Shell moderately small and slender; ivory-white in colour, ornamented with irregular reddish-brown blotches which appear darker in the intercostal spaces. Whorls slightly convex, numbering from 15 to 20, apart from protoconch of  $2\frac{1}{2}$  to 3 violet or amber-coloured nuclear whorls; presutural band defined by an almost obsolete punctate spiral groove. Sculpture consists of close-set straight or only slightly curved rounded whitish axial ribs

numbering from 19 to 21 on the penultimate whorl; axial ribs become generally lighter in colour towards the sutures. Intercostal spaces with 7 to 15 spiral lirae which extend halfway up the walls of the axial ribs. Body whorl with an ill-defined white transverse band, ultimate third of whorl reddish-brown; the body whorl has 17 to 19 intercostal lirae and 4 to 6 fine peripheral spiral cords. Columella light tan in colour, corded at edges and centrally undulate; anterior canal recurved.

**Size:** 14 to 38 mm.

**Habitat:** In clean sand, often in sand-pockets of coral reefs, from 0 to 5 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. – New Guinea, Queensland.

**Discussion:** The co-ordinates of Wading Island, the type locality, were erroneously stated as Lat. 17° 45' S and Longitude 177° 25' E in the original description. This should be emended to Lat. 17° 49' 20" S and Long. 177° 09' 30" E.

We have seen specimens of this species from Pearl Reef, Great Barrier Reef, Queensland (leg. D. Macpherson, collection Cernohorsky).

Paratype no. 17 of *Terebra kilburni* BURCH, collected at Lomalagi by the senior author and measuring 16.3 mm in length, has been deposited at the British Museum (Nat. Hist.), where it bears the Museum registry no. 1965141.

16. *Terebra (Decorihastula) nebulosa* SOWERBY, 1825

(Plate 5, Figure 27)

1825. *Terebra nebulosa* SOWERBY, Tank. Cat., App. p. 25

**Shell:** Shell moderate in size, slightly broadening towards aperture; ivory-white in colour, ornamented with moderately large irregular orange-red or carmine blotches. Whorls flat to slightly convex, numbering from 17 to 22 apart from protoconch; presutural band defined by a punctate spiral groove, with the deep pits in the intercostal spaces stained orange-red. Sculpture consists of moderately broad curved and somewhat rounded axial ribs, which become perpendicular on the presutural band and number from 18 to 26 on the penultimate whorl. Intercostal spaces with moderately shallow spiral grooves, numbering from 10 to 15 per whorl; grooves on early whorls just about extend to the summits, but on the last 3 to 4 whorls they override the axial ribs. Body whorl with orange-red irregular blotches and a narrow peripheral line of the same colour followed by a narrow white zone and spiral striae and an ultimate broad pinkish-tan transverse band which enters the aperture. Columella pinkish-tan or rose-red, slightly recurved,

corded, and centrally striate; interior of aperture orange-tan.

**Size:** 26 to 73 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands – From South Africa through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

**Discussion:** In some specimens the base colour is reddish-orange and the blotches appear white, in others the pattern is reversed.

17. *Terebra (Decorihastula) paucistriata*  
(E. A. SMITH, 1873)

(Plate 5, Figures 31, 31 a)

1873. *Myurella paucistriata* E. A. SMITH, Ann. Mag. Nat. Hist., 11 (4): 269

**Shell:** Shell small, slender and glossy, light yellowish-orange in colour. Whorls slightly convex, numbering from 16 to 17 apart from protoconch of 3½ nuclear whorls; the presutural band is defined by a moderately deep spiral groove, forming a double row of white beads at the sutures. The row of beads posteriorly to the sutures is coarse and well defined while the anterior row is weak and indicated by being white. Sculpture consists of elevated coarse and sharply angulate whitish axial ribs numbering from 10 to 12 on the penultimate whorl; axial ribs only slightly curved on the last two whorls but straight, obliquely oriented and contiguous on earlier whorls. Intercostal spaces deep and "V"-shaped, stained with yellowish-orange and with 3 to 8 transverse grooves which do not quite extend to the summits of the axial ribs. Body whorl somewhat angulate with 4 to 5 spiral grooves on its ultimate third and with a distinct white peripheral band. Columella straight, white and corded; interior of aperture whitish at the margin, fawn to orange in the interior.

**Size:** 18 to 32 mm.

**Habitat:** In clean sand, from 0 to 2 fathoms.

Moderately rare.

**Distribution:** Throughout the Fiji Islands. – ?

**Discussion:** *Terebra paucistriata* differs from *T. undulata* GRAY in colouring, by being more slender in shape, with angulate body whorl, deep intercostal spaces, and a white peripheral band which is absent in *T. undulata*. *Terebra paucistriata* differs from *T. (Decorihastula)* species in the latter having a shallower presutural groove, more numerous and curved axial ribs and intercostal grooves, a

rounded body whorl and is lacking the sheen of *T. paucistriata*.

The holotype is preserved in the British Museum (Nat. Hist.) where it bears the number B.M.N.H.1856.11.3.17, and measures 18.5 mm in length; it was dredged by J. McGillivray in 5 fathoms in sand at Ovalau Island, Fiji (S. P. Dance, *in litt.*).

18. *Terebra (Decorihastula) pertusa* (BORN, 1780)

(Plate 4, Figures 11, 11 a)

1780. *Buccinum pertusum* BORN, Mus. Caes. Vindob., p. 267, pl. 10, fig. 13  
 1829. *Terebra undata* BLAINVILLE, Dict. Sci. Nat., p. 35  
 1857. *Terebra bermonti* LORIS, Journ. Conchyl., p. 389, pl. 12, fig. 2  
 1898. *Terebra andamanica* MELVILL & SYKES, Proc. Malacol. Soc. London, 3 (1): 41, pl. 3, fig. 3  
 1903. *Terebra loisiae* E. A. SMITH, Proc. Malacol. Soc. London, 5 (6): 360, pl. 15, fig. 1

**Shell:** Shell moderately large, fairly solid; light or dark orange or yellow, ornamented with irregular curved white axial streaks and a narrow transverse band alternating in dark reddish-brown and white streaks at the sutures. Whorls almost flat and straight, numbering from 16 to 19 apart from protoconch; presutural band defined by a shallow spiral groove which is pitted between axial ribs anteriorly to the suture. Sculpture consists of weakly defined curved and angulate axial ribs which bisect the presutural band at an angle; axial ribs number from 25 to 35 on the penultimate whorl. Intercoastal spaces with 2 to 5 spiral grooves which almost reach the summits of the axial ribs. Body whorl with 8 to 9 intercoastal lirae followed by 3 to 4 spiral cords and a faint white peripheral band. Columella creamy-tan or orange, corded on the inner margin with a prominent cord extending from the centre to the outer edge of the canal.

**Size:** 30 to 70 mm.

**Habitat:** In clean and slightly muddy sand, from 0-3 fathoms.

Rare.

**Distribution:** South and West Viti Levu. - From the Red Sea through the tropical Indo-Pacific to the Hawaiian Islands.

**Discussion:** This species generally lives on clean sand substrate, however, it has also been dredged from Akuilau Island in Nadi Bay; this island is subject to occasional inundation of muddy water from nearby river deltas.

*Terebra andamanica* MELVILL & SYKES has been compared with *T. pertusa* (BORN) by the authors but was specifically separated on the basis of being broader with more convex whorls (not apparent in figure), more ele-

vated longitudinal sculpture, more prominent infrasutural band and irregular spotting in which the spots are farther apart. All these features may be observed within even a short series of *T. pertusa*. *Terebra loisiae* SMITH appears to be a small damaged and bleached specimen of *T. pertusa* (BORN).

19. *Terebra (Decorihastula) undulata* GRAY, 1834

(Plate 5, Figure 29)

1834. *Terebra undulata* GRAY, Proc. Zool. Soc. London, p. 61  
 1839. *Terebra pertusa* KIENER (pars), Spéc. Gen. Icon. Coq. Viv., pl. 11, fig. 24 c (non *Buccinum pertusum* BORN, 1780)  
 1859. *Terebra approximata* DESHAYES, Proc. Zool. Soc. London, p. 299, no. 125  
 1913. *Terebra undulata* var. *laevior* SCHEPMAN, Siboga Exp. Toxog., p. 372, no. 21, pl. 25, fig. 9

**Shell:** Shell moderately small, slightly ventricose; fawn or light brown in colour, intercoastal spaces stained dark brown. Whorls flat or slightly convex, numbering from 12 to 18, apart from protoconch; presutural band defined by a punctured spiral groove which bisects axial ribs to form a single row of axially oriented white beads. Sculpture consisting of curved, rounded lighter-coloured axial ribs numbering from 13 to 20 on the penultimate whorl. Intercoastal spaces with from 4 to 10 deep spiral grooves which extend onto the walls of the axial ribs. Body whorl axially plicate, with 5 to 10 shallow spiral striae anteriorly to the siphonal canal. Columella flesh to light tan in



Figure 7

Operculum of *Terebra undulata* GRAY

colour, slightly recurved with a thin brown cord on the inner margin; interior of aperture tan in colour.

**Size:** 15 to 60 mm.

**Habitat:** In clean and slightly muddy sand, from 0-2 fathoms.

Moderately uncommon.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands through the tropical Pacific to Polynesia and Hawaii.

20. *Terebra* (*Decorihastula*) species

(Plate 5, Figure 30)

**Shell:** Shell small and slender; light orange to orange-brown in colour, intercostal spaces stained dark orange. Whorls slightly convex, numbering from 14 to 17, apart



Figure 8

Opérculum of *Terebra* (*Decorihastula*) species

from protoconch of 3 nuclear whorls; presutural band defined by a shallow punctured spiral groove. Sculpture consists of curved and slightly angulate axial ribs numbering from 13 to 21 on the penultimate whorl; the white presutural band may be narrow or slightly broader forming a single or double row of small beads at the sutures. Intercostal spaces with from 5 to 11 deep spiral grooves which extend onto the walls of the axial ribs. Body whorl axially plicate with a narrow white peripheral band and from 5 to 9 subsequent spiral cords; ultimate third of body whorl pale orange. Columella long and straight, flesh or pale orange, plicate interiorly and corded exteriorly; aperture elongate, interior pale orange with a white median band.

**Size:** 17 to 37 mm.

**Habitat:** In clean sand, from 0 - 5 fathoms.

Uncommon.

**Distribution:** South and West Viti Levu. – From the Philippine Islands to Fiji.

**Discussion:** The species differs from *Terebra undulata* GRAY in being more slender, orange-brown in colour, and having more numerous and finer axial ribs and transverse grooves, and being ornamented with a white peripheral line on the body whorl. It differs from *T. columellaris* HINDS in colour pattern and in having slightly longer whorls with fewer axial ribs and a longer columella and aperture.

This species has been reported as *Terebra paucistriata* (E. A. SMITH) from Fiji by CATE & BURCH (1964).

(*Perirhoe*) DALL, 1908

**Type species:** *Terebra circumcincta* DESHAYES, 1857.

21. *Terebra* (*Perirhoe*) *amanda* HINDS, 1844

(Plate 5, Figure 17)

1844. *Terebra amanda* HINDS, Proc. Zool. Soc. London for 1843: p. 154

**Shell:** Shell moderately small and slender; fawn to light brown in colour and shining. Whorls flat to slightly concave, numbering from 14 to 18, apart from protoconch of  $2\frac{1}{2}$  to  $3\frac{1}{2}$  light fawn nuclear whorls; presutural band defined by a deep spiral groove which is often punctate, the spiral groove separating two rows of distinct squarish and slightly concave sutural beads. Sculpture consists of 3 to 4 spiral rows of deep punctures on the whorls, pittings numbering about 30 on the penultimate whorl. Body whorl with a double row of beads, followed by 3 to 4 spiral punctations and 5 to 8 spiral grooves which enter the aperture. Columella cream in colour, calloused, plicate and rounded; interior of aperture light fawn, anterior canal recurved.

**Size:** 25 to 46 mm.

**Habitat:** In clean sand, from 0 - 15 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands to Fiji and the Hawaiian Islands.

**Discussion:** The two rows of sutural beads are of equal size on the early whorls, but the anterior row of beads becomes slightly smaller towards the aperture.

22. *Terebra* (*Perirhoe*) *anilis* (RÖDING, 1798)

(Plate 5, Figure 15)

1791. *Buccinum strigilatum* GMELIN (pars), Syst. Nat., ed. 13, p. 3501 (non LINNAEUS, 1758)

1798. *Epitonium anile* RÖDING, Mus. Bolten., p. 95

1798. *Epitonium cancellatum* RÖDING, Mus. Bolten., p. 95

1822. *Terebra myuros* LAMARCK, Anim. sans Vert., 7: 289

1843. *Terebra scabrella* DESHAYES & MILNE-EDWARDS, Anim. sans Vert., 2nd. ed., 10: 247

1857. *Terebra acuta* DESHAYES, Journ. Conchyl., 6: 100, pl. 4, figs. 4, 5

1857. *Terebra circinata* DESHAYES, Journ. Conchyl., 6: 99, pl. 4, figs. 6, 7

**Shell:** Shell small and slender; light to dark tan in colour throughout. Whorls concave, numbering from 18 to 20, apart from protoconch of  $1\frac{1}{2}$  nuclear whorls; presutural

band defined by a deep spiral groove separating two rows of oblique and slightly angulate beads, with the anterior row always the larger. Sculpture consists of curved, broad and slightly angulate axial ribs, numbering about 21 on the penultimate whorl; axial ribs fairly straight on the first four postnuclear whorls. Whorls encircled with from 4 to 7 spiral grooves, grooves bisecting axial ribs to give the whorls a beaded effect. Body whorl axially plicate, spirally striate, and with a peripheral row of small beads. Columella light tan in colour, flat and recurved, corded on margins; interior of aperture light tan.

Size: 30 to 45 mm.

Habitat: In clean sand, from 10 - 15 fathoms.

Moderately rare.

**Distribution:** South and West Viti Levu. - From the Philippine Islands to Fiji and Samoa.

**Discussion:** We have examined specimens of the species from Asau and Apia harbours, Samoa (*leg.* T. Jackson), which hardly differed from Fiji specimens.

This species has been reported as *Terebra cumingi* DESHAYES, from Fiji by J. CATE & BURCH (1964).

### 23. *Terebra (Perirhoe) babylonia* LAMARCK, 1822

(Plate 5, Figure 25)

1791. *Buccinum acus* GMELIN, Syst. Nat., ed. 13, p. 3502 (*nomen oblitum*)

1822. *Terebra babylonia* LAMARCK, Anim. sans Vert., 7: 287

1834. *Terebra striata* GRAY, Proc. Zool. Soc. London, p. 60 (*non* BASTEROT, 1825; *nec* QUOY & GAIMARD, 1832)

1838. *Terebra babylonica* POTIEZ & MICHAUD, Gal. de Donai, 1: p. 393

**Shell:** Shell moderately small and slender; flesh in colour, ornamented with orange-brown axial growth striae and spiral grooves. Whorls flat or only slightly convex, numbering about 19, apart from protoconch of 2 nuclear



Figure 9

Operculum of *Terebra babylonia* LAMARCK

whorls; presutural band defined by a deep smooth spiral groove. Sculpture consists of 2 moderately deep and smooth spiral grooves and dark flesh or orange-brown

curved axial striae which bisect the presutural band to form one or two rows of light-coloured longitudinally oriented indistinct oblong beads; beads are arranged in a double row on early whorls and become generally reduced to only one row of obsolete beads on the last three whorls. Body whorl with 2 to 3 spiral grooves anteriorly to the sutures and a broad dark flesh or orange-brown spiral band on the ultimate half of the whorl; the coloured band contains five spiral striae. Columella flesh-brown in colour, plicate at outer margin and with a flat calloused area which joins lip at suture; anterior canal recurved, interior of aperture flesh-brown.

Juvenile shells have two rows of beads on all whorls and an additional row of beads on the body whorl.

Size: 15 to 76 mm.

Habitat: In clean sand, from 0 - 3 fathoms.

Moderately common.

**Distribution:** Throughout the Fiji Islands. - From the Red Sea through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** The species was figured but not formally named by LAMARCK in 1816 (pl. 402, fig. 5).

### 24. *Terebra (Perirhoe) cingulifera* LAMARCK, 1822

(Plate 5, Figures 18, 18a)

1822. *Terebra cingulifera* LAMARCK, Anim. sans Vert., 7: 289

1825. *Terebra punctulata* SOWERBY, Tank. cat., App. p. 24

1834. *Terebra punctatostriata* GRAY, Proc. Zool. Soc. London, p. 61

1859. *Terebra chinensis* DESHAYES, Proc. Zool. Soc. London, p. 309, no. 189

1859. *Terebra columnaris* DESHAYES, Proc. Zool. Soc. London, p. 310, no. 195

**Shell:** Shell moderate in size, slender and smooth; pale flesh to light tan in colour, presutural band occasionally lighter in colour. Whorls slightly concave or flat, rarely slightly convex, numbering from 15 to 20, apart from protoconch of 3 glassy nuclear whorls; presutural band defined by a moderately deep spiral groove, which may be either smooth or punctate. Sculpture consists of from 2 to 7 shallow punctate spiral lines and curved almost obsolete axial growth striae; these growth axials are more pronounced in some individuals than in others. Early whorls concave, with more pronounced spiral grooves and a double row of beads at sutures. Body whorl with numerous punctate spiral lines which become close-set towards the siphonal canal; columella pinkish-white, straight or slightly recurved, with a single raised cord; interior of aperture flesh coloured.

Size: 27 to 75 mm.

**Habitat:** In clean sand, from 0 - 5 fathoms.

Moderately uncommon.

**Distribution:** Throughout the Fiji Islands. – From Mauritius through the tropical Indo-Pacific to Samoa.

**Discussion:** The species is variable in colouring and form of whorls. The post-sutural roll is distinct in some specimens but almost flat in others. While end-members of a population may appear specifically separable, intergradation is obvious in a long series of specimens.

25. *Terebra (Perirhoe) funiculata* HINDS, 1844

(Plate 5, Figure 22)

1844. *Terebra funiculata* HINDS, Proc. Zool. Soc. London for 1843: 153

1859. *Terebra archimedis* DESHAYES, Proc. Zool. Soc. London, p. 314

**Shell:** Shell small and slender; dirty-white to creamy-fawn in colour. Whorls slightly concave, numbering from 17 to 19, apart from protoconch of 3 glassy nuclear whorls; presutural band is divided into two strong spiral cords by a deep transverse groove; the posterior presutural cord is traversed by a shallow spiral groove forming a smaller additional satellite cord. Whorls with generally two spiral grooves and axially curved growth lines; all grooves are stained with orange or orange-brown. Body whorl with 2 rounded presutural cords, followed by 2 to 3 spiral grooves; columella white, with a thin brown cord. Anterior canal prominently recurved, interior of aperture white.

**Size:** 15 to 32 mm.

**Habitat:** In clean, slightly muddy and silty sand, from 0 to 5 fathoms.

Uncommon.

**Distribution:** South and West Viti Levu. – From the Philippine Islands through the tropical Pacific to Polynesia and Hawaii.

**Discussion:** *Terebra funiculata* HINDS appears to occur in isolated and widely separated colonies in Fiji, and is generally not found in exposed areas.

26. *Terebra (Perirhoe) laevigata* GRAY, 1834

(Plate 5, Figure 21)

1834. *Terebra laevigata* GRAY, Proc. Zool. Soc. London, p. 61

1964. *Terebra (Perirhoe) archimedis* (sic) DESHAYES, J. CATE & BURCH, The Veliger 6 (3): 146 (non *Terebra archimedis* DESHAYES, 1859)

**Shell:** Shell moderately small and slender; creamy-white to light fawn in colour throughout. Whorls flat to slightly

concave, numbering from 19 to 26, apart from protoconch of 1½ nuclear whorls; presutural band defined by a moderately deep spiral groove, separating two distinct spiral cords at the sutures; the anterior cord becomes appreciably smaller and sometimes even obsolete on the whorls towards the aperture. Sculpture consists of from 3 to 8 extremely fine spiral striae, which are generally more pronounced in larger specimens, and numerous axially curved growth lines. Body whorl with 10 to 15 fine spiral striae; columella whitish, smooth, but occasionally with a raised plication, corded on the exterior; interior of aperture light cream.

**Size:** 27 to 50 mm.

**Habitat:** In clean and muddy sand, from 0 to 10 fathoms.

Moderately uncommon.

**Distribution:** Throughout the Fiji Islands – From South Africa through the tropical Indo-Pacific to Fiji.

27. *Terebra (Perirhoe) langfordi* PILSBRY, 1921

(Plate 5, Figure 23)

1921. *Terebra langfordi* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 303

1921. *Terebra langfordi angustior* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 304

**Shell:** Shell moderately small, heavy and slender; fawn to yellowish-brown in colour throughout. Whorls flat, shouldered below suture, numbering from 15 to 18, apart from protoconch; presutural band defined by a deeply incised punctate spiral groove, separating two distinct rounded spiral cords; the posterior spiral cord is slightly more prominent and is traversed by a fine punctate transverse groove. Whorls with 4 distinct spiral grooves and numerous fine axially curved growth striae which give the intervening grooves a cancellate appearance. Body whorl with five somewhat flattened spiral cords, the fifth peripheral cord slightly more pronounced, followed by 7 to 10 finer spirals. Columella white, recurved, corded on either side, with a shining white calloused area near aperture; interior of aperture whitish.

**Size:** 30 to 40 mm.

**Habitat:** In clean sand and soft weed substrate, from 3 to 5 fathoms.

Rare.

**Distribution:** Namotu Islands, West off Viti Levu. – Hawaiian Islands.

**Discussion:** This species has been believed to be endemic to the Hawaiian Islands, and the Fiji record appears to be the first outside this region.

*Terebra funiculata* HINDS superficially resembles this species, but the former is more fragile, has a lighter-col-

oured shell, with only two spiral grooves on whorls, and the body whorl bears only 2 to 3 spiral cords which are following the four main cords.

28. *Terebra (Perirhoe) montgomeryi* R. D. BURCH, 1965  
(Plate 5, Figure 20)

1965. *Terebra (Dimidacus) montgomeryi* R. D. BURCH, *The Veliger*, 7 (4): 250-251, pl. 31, fig. 7 (Type locality: Guam, Mariana Islands)

**Shell:** Shell moderate in size, slender and smooth; orange-brown in colour, ornamented with moderately large irregular and axially curved white flammules. Whorls flat, numbering 18, apart from protoconch, which is eroded; presutural band defined by a shallow punctate spiral groove. Sculpture consists of 4 spiral rows of deep punctures and curved axial growth lines which become close-set and ill-defined weak axial ribs at the presutural band; these axials number about 47 on the penultimate whorl. Body whorl with 4 spiral rows of deep punctures, followed by 8 to 10 spiral grooves, some of which are punctate. Columella whitish, twisted, and with a single cord; interior of aperture light orange-fawn.

**Size:** 50.5 mm.

**Habitat:** In clean sand, in shallow water.

Very rare.

**Distribution:** Mamanuca group, West off Viti Levu. - Guam.

**Discussion:** The species resembles *Terebra cingulifera* LAMARCK but differs in colour pattern, having a shallow presutural groove, spiral rows of disconnected punctures, and not continuous punctate spiral grooves as in *T. cingulifera*.

The holotype has been described from Guam by R. D. BURCH (1965), and the hypotype no. 1 was stated to have come from "Natadola Island." This hypotype, however, has been collected by the junior author 100 yards off the eastern sector of Namotu Island in the Mamanuca group.

29. *Terebra (Perirhoe) pallida* DESHAYES, 1857

(Plate 5, Figure 19)

1857. *Terebra pallida* DESHAYES, *Journ. Conchyl.*, 6: 87, pl. 4, fig. 3

1931. *Perirhoe exulta* IREDALE, *Rec. Austral. Mus.*, 18: 224, pl. 25, fig. 3

**Shell:** Shell large and slender, slightly ventricose; reddish-brown to dark tan in colour throughout. Whorls convexly

rounded, numbering 20 to 26, apart from protoconch; presutural band defined by a narrow smooth spiral groove which bisects narrow, obliquely oriented axial ribs; ribs are short, almost obsolete, and confined to the presutural band. Sculpture consists of narrow moderately deep smooth spiral grooves, numbering from 4 to 8 on the penultimate whorl; early whorls with a double row of rounded nodules at the sutures. Body whorl with 14 to 19 fine spiral grooves, grooves somewhat obsolete in central area of body whorl; columella tan in colour, recurved, corded on either side, with a prominent angulate cord extending from the outer edge of the anterior canal; the columella forms a calloused area on the body whorl.

**Size:** 70 to 102 mm.

**Habitat:** In clean sand, from 0-5 fathoms.

Uncommon.

**Distribution:** West and South Viti Levu. - Australia, Polynesia.

**Discussion:** This species has on occasions been associated with *Terebra cingulifera* LAMARCK, but differs from that species in being much larger in size, orange-brown in colour, ventricose, with subulate convexly-rounded whorls and smooth spiral grooves.

30. *Terebra (Perirhoe) succinea* HINDS, 1844

(Plate 4, Figure 10)

1844. *Terebra succinea* HINDS, *Proc. Zool. Soc. London* for 1843: p. 149

1844. *Terebra succinea* HINDS in SOWERBY, *Thes. Conch.*, p. 151, pl. 42, fig. 40

**Shell:** Shell moderate in size, salmon-pink or orange-brown in colour, ornamented with two rows of small wide-spaced dark brown spots on whorls. Whorls flattened numbering 16, apart from protoconch, which is eroded. Sculpture consists of 4 to 10 weakly defined punctate spiral grooves or ridges and fine, close-set and arcuate growth-striae; presutural band defined by a moderately shallow spiral groove which is generally lighter in colour. Body whorl with three rows of small brown spots, ultimate row entering aperture. Columella salmon-pink in colour, with a weak columellar fold and a sharp cord on the exterior.

**Size:** 73 to 78 mm.

**Habitat:** In clean sand, in shallow water.

Rare.

**Distribution:** South and West Viti Levu. - Guam.

**Discussion:** Only three live-collected specimens are known to have been taken in Fiji waters (*leg.* M. Freitag and K. Mijts). Three specimens of this species have been recently recorded from Guam (R. D. BURCH, *in litt.*).



31. *Terebra (Perirhoe)* species

(Plate 5, Figure 16)

1964. *Terebra (Perirhoe) anilis* (RÖDING), J. CATE & BURCH, The Veliger 6 (3): 146 (non *Epitonium anilis* RÖDING, 1798)

**Shell:** Shell moderate in size, slender; dark tan in colour throughout. Whorls flat, becoming concave on early whorls numbering from 21 to 24, apart from a glassy-white protoconch; presutural band defined by a deep smooth spiral groove which separates a double row of blunt oblique beads; the row of beads posterior to the sutures always appreciably the larger, beads becoming obsolete on the ultimate three whorls in large specimens. Sculpture consists of 4 to 6 fine smooth spiral grooves and a single slightly raised cord just posterior to the sutures; grooves are bisected by fine axially curved growth striae, giving the whorls a cancellate appearance. On the first 8 to 10 whorls the double rows of beads are of equal size. Body whorl with 4 spiral grooves, one raised peripheral flattish spiral cord which is followed by 7 to 10 spiral striae. Columella light tan in colour, recurved, corded on inner margin and forming a light tan calloused area on body whorl; aperture rounded, light tan interiorly. Size: 36 to 55 mm.

**Habitat:** In clean sand, from 0 - 15 fathoms.

Moderately rare.

**Distribution:** Throughout the Fiji Islands. – ?

**Discussion:** The species differs from *Terebra cingulifera* LAMARCK in being dark tan in colour, with more numerous whorls and a more recurved columella and smooth spiral grooves; the sutures are nodulose and the body whorl is less rounded and slightly angulate. It differs from *T. pallida* DESHAYES in being appreciably smaller, and not subulate, and having flat whorls and beaded sutures.

The species has been collected in several Fijian localities, and all specimens exhibit common diagnostic features. The species does not appear to exceed 55 mm, with the majority of specimens ranging from 40 to 45 mm in length.

(*Strioterebrum*) SACCO, 1891

**Type species:** *Terebra basteroti* NYST, 1843 (fossil species).

32. *Terebra (Strioterebrum) exigua* DESHAYES, 1859

(Plate 6, Figure 38)

1859. *Terebra exigua* DESHAYES, Proc. Zool. Soc. London, p. 301

1944. *Terebra textilis* TOMLIN, Journ. Conch., 22 (5): 106 (non HINDS, 1844)

**Shell:** Shell very small and slender; brownish-fawn in colour with a light fawn presutural band. Whorls moderately convex, numbering from 15 to 17, apart from protoconch of  $3\frac{1}{2}$  glassy light violet nuclear whorls; presutural band defined by a spiral groove which is shallow on the apex of the axial ribs but deep in interstices and stained a darker fawn. Sculpture consists of elevated, curved and angulate axial ribs numbering from 15 to 16 on the penultimate whorl. Intercoastal spaces with flattened spiral cords number from 3 to 4 on the presutural band and from 7 to 8 on the body whorl; cords extend to the summits of the axial ribs, area between cords microscopically transversely striate. Body whorl axially plicate and with 23 to 27 spiral striae; columella light brownish-fawn, moderately recurved, plicate interiorly, corded on outer margin, and with a pronounced elevated calloused area extending onto the body whorl; interior of aperture dark fawn.

**Size:** 24 to 28 mm.

**Habitat:** In clean sand, from 10 - 15 fathoms.

Rare.

**Distribution:** Momi Bay, West Viti Levu. – From New Guinea to Fiji.

33. *Terebra (Strioterebrum) fenestrata* HINDS, 1844

(Plate 6, Figure 37)

1844. *Terebra fenestrata* HINDS, Proc. Zool. Soc. London for 1843: p. 153

1844. *Terebra fenestrata* HINDS in SOWERBY, Thes. Conch., p. 176, pl. 44, fig. 86

**Shell:** Shell small and moderately slender; cream to fawn in colour, occasionally with a few yellowish axial streaks. Whorls straight to slightly concave, numbering 17, apart from protoconch of  $3\frac{1}{2}$  white nuclear whorls. Sculpture consists of angulate and slightly curved axial ribs, numbering 22 on the penultimate whorl; sutures with two rows of beads which are separated by a deep presutural groove; in the interior row the beads are axially oriented oblique nodules and larger than the posterior row which consists of round angulate beads; on early whorls beads are equal in size. Interstices of axial ribs with about 4 elevated spiral ridges which override axial ribs to form small beads on the ribs; the interspaces of the main spiral ridges are very finely spirally striate. Body whorl axially ribbed and spirally ridged; columella creamy-white, prominently plicate, with a sharp thin cord extending to the anterior canal. Siphonal canal prominently recurved, twisted and tapered to a point.

Size: 28 to 32 mm.

Habitat: Unknown. Known from collection of dead specimens only.

Distribution: South Viti Levu. – ?

34. *Terebra (Strioterebrum) flavescens* DESHAYES, 1859

(Plate 6, Figure 34)

1859. *Terebra flavescens* DESHAYES, Proc. Zool. Soc. London, p. 299, no. 122

Shell: Shell small, moderately heavy and slender; light tan to brown in colour throughout. Whorls moderately convex, numbering from 13 to 16, apart from protoconch of 3 glassy violet nuclear whorls; presutural band defined by a deep spiral groove, sutures deep and with a noticeable presutural roll. Sculpture consists of curved and rounded axial ribs which extend onto the presutural band to form oblique, longitudinally oriented narrow beads; axial ribs number from 20 to 23 on the penultimate whorl. Intercoastal spaces broad with 8 to 9 elevated spiral cords which extend to the summits of the ribs; in certain individuals spiral cords override axial ribs, making these appear finely beaded; cords interrupted by a somewhat broad presutural groove, but 3 to 4 cords continue on the sutural nodules. Body whorl axially plicate, with

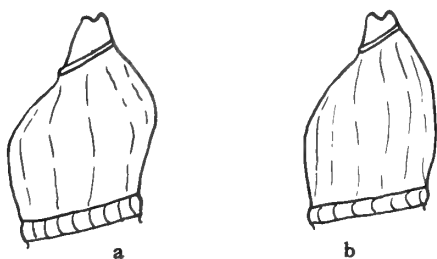


Figure 10

a – Lateral view of body whorl of *Terebra succincta* (GMELIN)

b – Lateral view of body whorl of *Terebra flavescens* DESHAYES

15 to 17 transverse cords in intercoastal spaces; columella creamy-tan to dark brown, concave, undulate slightly recurved and corded on either side, a calloused elevated area extends onto body whorl, interior of aperture light brown.

Size: 30 to 45 mm.

Habitat: In clean sand, from 3 to 5 fathoms.

Moderately rare.

Distribution: South and West Viti Levu. – Australia.

**Discussion:** The species is similar to *Terebra succincta* (GMELIN) but differs in being tan in colour, with a deep presutural groove, rounded axial ribs and more elevated longer intercoastal grooves; the aperture is distinctly laminated in adult specimens and the body whorl lacks the bulbous appearance of *T. succincta*.

35. *Terebra (Strioterebrum) succincta* (GMELIN, 1791)

(Plate 6, Figure 35)

1791. *Buccinum succinctum* GMELIN, Syst. Nat., ed. 13, p. 3502

1798. *Epitonium fissum* RÖDING, Mus. Bolten., p. 95

1807. *Vertagus succinctus* LINK, Besch. Nat.-Samml. Univ. Rosstock, p. 129

1832. *Terebra cancellata* QUOY & GAIMARD, Voy. Astrol, 2: 471, pl. 36, figs. 27, 28 (non *Epitonium cancellatum* RÖDING, 1798)

1859. *Terebra undatella* DESHAYES, Proc. Zool. Soc. London for 1843: 300, no. 129

Shell: Shell moderately small, slender and heavy; dark brown to almost black in colour throughout. Whorls convex, numbering from 14 to 17, apart from protoconch of 2 nuclear whorls; presutural band defined by a moderately deep spiral groove. Sculpture consists of curved slightly angulate axial ribs, numbering from 20 to 28 on the penultimate whorl, ribs bisecting presutural band at an angle. Intercoastal spaces with broad transverse ridges, numbering from 6 to 11 and almost reaching the summits of the axial ribs. Body whorl bulbous, axially plicate, with numerous spiral cords which override axial ribs towards the columella and terminate at the columellar cord. Columella dark brown, straight or recurved, plicate interiorly and strongly corded exteriorly; aperture elongate, dark brown within.

Size: 16 to 38 mm.

Habitat: In soft muddy sand, in shallow water.

Common in the West of Viti Levu, uncommon elsewhere.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands through the tropical Pacific to Fiji and the Hawaiian Islands.

**Discussion:** The species occurs in widely separated colonies in Fiji, due to the preferential soft muddy sand environment; it is conspicuously rare in the North-east of Viti Levu.

*Terebra cancellata* QUOY & GAIMARD is a secondary homonym of *Epitonium cancellatum* RÖDING, 1798 (= *E. anilis* RÖDING, 1798). *Terebra cancellata* QUOY & GAIMARD is congeneric with *T. anilis* (RÖDING), and both are placed in the genus *Terebra* s. str. by almost all writers.

*Buccinum succinctum* GMELIN and *Epitonium fissum* were both based on a delineation in CHEMNITZ (1780,

vol. 4, pl. 154, fig. 1451) which represents the species *Terebra cancellata* QUOY & GAIMARD. The species has been figured by WOOD (1828, pl. 24, fig. 144) as *B. succinctum* GMELIN.

36. *Terebra (Strioterebrum) textilis* HINDS, 1844

(Plate 6, Figure 36)

1844. *Terebra textilis* HINDS, Proc. Zool. Soc. London for 1843: p. 156

**Shell:** Shell small and slender; creamy-white to light yellow in colour throughout, occasionally stained with light orange in intercostal spaces. Whorls convex, numbering from 12 to 18, apart from protoconch of  $3\frac{1}{2}$  to 4 glassy, light violet nuclear whorls; presutural band defined by a moderately deep spiral groove. Sculpture consists of slightly curved angulate axial ribs, numbering from 16 to 22 on the penultimate whorl. Intercostal spaces with fine



Figure 11

Operculum of *Terebra textilis* HINDS

elevated spiral cords numbering from 5 to 16, cords almost reaching the summits of the axial ribs; the intercostal spaces deeply pitted on the presutural groove. Body whorl axially plicate, with 20 to 30 spiral striae overriding axial ribs towards the aperture; columella cream in colour, slightly recurved, centrally plicate, with a rounded cord on the inner margin and a prominent cord extending from the centre of the columella to the outer margin of the siphonal canal; columella extends as a slightly raised calloused area onto the body whorl, interior of aperture creamy-white.

**Size:** 14 to 40 mm.

**Habitat:** In clean and slightly muddy sand, from 0 - 5 fathoms.

Moderately uncommon.

**Distribution:** Throughout the Fiji Islands. - Through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands; not reported from the Philippine region.

37. *Terebra (Strioterebrum) turrita* (E. A. SMITH, 1873)

(Plate 6, Figures 40, 40a, 40b)

1873. *Myurella turrita* E. A. SMITH, Ann. Mag. Nat. Hist., 11 (4): p. 266

1964. *Terebra polygyrata* DESHAYES, J. CATE & BURCH, The Veliger, 6 (3): 147 (non DESHAYES, 1859)

**Shell:** Shell very small, narrow, and slender; brown in colour with a white presutural band. Whorls short and shouldered; slightly convex, numbering from 15 to 18, apart from protoconch; presutural band defined by a deep spiral groove bisecting axial ribs to form angulate longitudinally-oriented white nodules. Sculpture consists of slightly curved elevated and angulate axial ribs, numbering from 15 to 21 on the penultimate whorl. Intercostal spaces with from 4 to 6 slightly elevated fine spiral cords which override the ribs to make them appear finely beaded; an additional 3 to 6 spiral cords are situated between the sutural nodules and either barely reach or override nodules. Body whorl axially plicate, with from 12 to 16 fine spiral cords; the body whorl is brown in colour with a moderately broad, white peripheral band. Columella light grey, tan or brownish-mauve, slightly recurved and centrally grooved, extending onto the body whorl as a slightly raised calloused area.

**Size:** 15 to 23 mm.

**Habitat:** In clean sand, from 10 - 15 fathoms.

Rare.

**Distribution:** Momi Bay, West off Viti Levu. - ?

**Discussion:** The holotype, Cuming collection, is in the British Museum (Nat. Hist.) where it bears the number B.M.N.H. 1965137, and measures 23 mm in length (S. P. Dance, *in litt.*). SMITH (1873, p. 266) gives the length as 26 mm; the holotype is a dead, bleached specimen.

(*Clathroterebra*) OYAMA, 1961

**Type species:** *Terebra fortunei* DESHAYES, 1857.

38. *Terebra (Clathroterebra) fijiensis*

(E. A. SMITH, 1873)

(Plate 6, Figure 42)

1873. *Myurella fijiensis* E. A. SMITH, Ann. Mag. Nat. Hist., 11 (4): p. 266

**Shell:** The species has been described by SMITH as follows: Shell small, subulate, shining white, whorls centrally weakly and obscurely banded with brown; whorls flattened, axial ribs moderately strong, oblique and slightly arcuate (on body whorl 13, gradually becoming obsolete towards the base), regular, transversely elegantly

corded (with 8 cords and 16 on body whorl); presutural zone not prominent; aperture small; columella almost straight, siphonal canal short.

Size: length, 21 mm; width, 4 mm

Habitat: In sand and mud, in 12 fathoms (S.P.Dance, *in litt.*).

Type locality: Ovalau Island, Fiji Islands (*leg. J. McGillivray*).

Discussion: SMITH (op. cit.) remarked that the chief characteristics of this species are the regularity of the spiral sulci, about eight in each whorl and double that number in the last, and the obscurity of the infrasutural spiral groove, which is only to be detected in the upper whorls and consists of a series of elongate punctures between the longitudinal ribs. The faint brownish band around the middle of the whorls is probably somewhat faded.

This species is unknown in recent collections; it is not the *Terebra fijiensis* SMITH, as of BURCH (1965) from Fiji. The holotype is in the British Museum (Nat. Hist.), where it bears the number B. M. N. H. 1856.10.27.8, and measures 19.8 mm (S.P.Dance, *in litt.*); it has obviously been dredged dead.

39. *Terebra (Clathroterebra) multistriata*  
SCHEPMAN, 1913

(Plate 6, Figure 39)

1913. *Terebra multistriata* SCHEPMAN, Siboga Exp., pt. 5, p. 371, pl. 25, fig. 8

Shell: Shell small and moderately slender; cream to light fawn in colour with a brown or dark yellow presutural band. Whorls short and convex, numbering from 16 to 17, apart from protoconch of 3 white, glassy nuclear whorls; presutural groove absent, but a rusty-brown or dark yellow presutural band is evident. Sculpture consists of elevated curved and moderately angulate axial ribs, numbering from 13 to 18 on the penultimate whorl; intercostal spaces with 10 to 15 fine elevated transverse ridges which extend to the apex of the axial ribs, making these appear finely beaded; space between the transverse ridges microscopically spirally striate. Body whorl axially plicate, ribs extending as far as the anterior canal, with numerous intercostal striae numbering from 25 to 40; a broad brownish peripheral band is visible on the body whorl. Columella white, slightly recurved, centrally grooved and corded exteriorly; a white calloused area extends onto the body whorl.

Size: 17 to 25 mm.

Habitat: Known from dead shells only, dredged from 10 to 15 fathoms.

Rare.

Distribution: Momi Bay, West off Viti Levu. – ?

40. *Terebra (Clathroterebra) species*

(Plate 6, Figure 41)

Shell: Shell very small, slightly broadening towards aperture; creamy-white in colour, with a violet columella and aperture. Whorls convex, numbering about 13, apart from protoconch of 3 glassy purplish whorls; presutural band defined by a spiral groove which is weak and shallow on the apex of the axial ribs but deeply punctate in intercostal spaces. Sculpture consists of curved and sharply angulate axial ribs, numbering about 14 on the penultimate whorl; intercostal spaces with 12 to 15 spiral grooves, with 4 of these grooves situated on the presutural band, remainder on whorl; spiral grooves become almost obsolete on early whorls. Body whorl with about 25 spiral lirae, half of these terminating inside of aperture; ultimate third of body whorl violet. Columella violet in colour, centrally concave, corded on either side of margin, exterior cord prominent; interior of aperture violet.

Size: 20 mm.

Habitat: Unknown. Dead specimen dredged from 10 to 15 fathoms on clean sand substrate.

Rare.

Distribution: Southwest Viti Levu. – ?

Discussion: The colour of live-collected specimens may differ somewhat from the well-preserved but dead-collected specimen from Fiji.

This species has been reported as *Terebra violascens* HINDS, by J. CATE & BURCH (1964) from Fiji; however, HINDS' type-figure differs appreciably from the Fiji specimen.

(*Triplostephanus*) DALL, 1908

Type species: *Terebra triseriata* GRAY, 1834

41. *Terebra (Triplostephanus) jenningsi* R.D.BURCH, 1965

(Plate 4, Figures 13, 13 a)

1965. *Terebra (Triplostephanus) jenningsi* R. BURCH, The Veliger, 7 (4): 248-249, pl. 31, fig. 9

Shell: Shell medium in size, very slender and long; orange-yellow or light flesh in colour with a white presutural band. Whorls flat to concave, numbering from 25 to 30,

apart from protoconch of  $2\frac{1}{2}$  white opaque nuclear whorls; presutural band defined by a white rounded cord at sutures. Whorls with 5 to 7 fine, lightly incised spiral grooves which are occasionally obsoletely punctate, and numerous protractially curved growth striae; early whorls light tan in colour, concave, with two rows of small crenules which become progressively obsolete towards the aperture; sutural crenules hardly visible on the last 3



Figure 12

Operculum of *Terebra jenningsi* R. BURCH

whorls in large specimens, whereas the crenules may be visible on the periphery of the body whorl in smaller specimens. Body whorl angulate, occasionally with a peripheral cord and 5 to 7 spiral lirae in between the sutures and cord; an additional 9 to 11 lirae are visible near the periphery of the body whorl and terminate near the calloused area of the columella. Columella creamy-flesh in colour, concave, strongly corded on interior margin and with a calloused area extending from siphonal canal to the upper centre of the columella; anterior canal sharply recurved, aperture ovate, interior creamy-white.

**Animal:** Foot cylindrical and narrow, truncated and broadening anteriorly, becoming roundly pointed posteriorly. Foot creamy-white or yellow, siphon simple and light yellow, becoming bright yellow at distal end; eye-stalks short and slender rounded at the tips, with black eyes placed only a short distance away from summits. Operculum narrowly-elongate, translucent orange-yellow. **Size:** 40 to 80 mm.

**Habitat:** In clean sand, often in sand-pockets of coral reefs, from 0 to 5 fathoms.

Moderately rare.

**Distribution:** Throughout the Fiji Islands. – From Malaysia to the Philippine Islands and Fiji.

**Discussion:** The species is sympatric with *Terebra triseriata* GRAY in two Fijian localities (Manava Island and

Suva Reef). It resembles *T. triseriata* only superficially, and differs in colour, sculpture and number of whorls.

In the original description of *Terebra jenningsi* (BURCH, 1965), certain data have been erroneously transcribed and a correction is in order. The coordinates of Namotu Island, the type locality, are Lat.  $17^{\circ} 50' 45''$  S and Long.  $177^{\circ} 12' 30''$  E. In table 5 (op. cit., p. 249), the holotype is shown as originating from Natadola; however, it has been collected at Namotu Island. Paratypes 4 to 6 have been collected at Manava Island, North Viti Levu, by the senior author, while paratype 9 should have been shown as collected at Nadi Bay. Paratype 10 has been collected at Viti Levu Bay, North-east Viti Levu.

Paratype no. 5 of *Terebra jenningsi*, collected at Manava Island by the senior author, and measuring 47.8 mm in length, has been deposited in the British Museum (Nat. Hist.), where it bears the register number 1965143.

#### 42. *Terebra (Triplostephanus) triseriata* GRAY, 1834

(Plate 4, Figure 14)

1834. *Terebra triseriata* GRAY, Proc. Zool. Soc. London, p. 62

**Shell:** Shell moderate in size, very slender; dark fawn to chestnut-brown in colour throughout. Whorls flattened to slightly concave, numbering from 32 to 41, apart from protoconch which is usually missing; presutural band defined by a deep smooth spiral groove which separates two rows of crenules at the sutures; in some specimens the posterior row of nodules is the larger of the two. Sculpture consists of 4 to 6 prominent spiral cords of varying width and faint arcuate growth lines or axial grooves; on some specimens the spiral cords are beaded. Body whorl angulate, spirally corded, peripheral cord very prominent and beaded, ultimate third of body whorl spirally striate. Columella orange-brown or fawn in colour, calloused and plicate; siphonal canal recurved.

**Size:** 80 to 100 mm.

**Habitat:** In clean sand, from 0 to 7 fathoms.

Rare.

**Distribution:** North and South Viti Levu. – From the Philippine Islands through the tropical Pacific to Polynesia.

*Duplicaria* DALL, 1908

**Type species:** *Buccinum duplicatum* LINNAEUS, 1758  
= *Duplicaria duplicata* (LINNAEUS)

*Duplicaria s. str.*43. *Duplicaria (Duplicaria)* species

(Plate 6, Figure 44)

1964. *Duplicaria australis* (E. A. SMITH), J. CATE & BURCH, The Veliger 6 (3): 145 (non *Terebra australis* E. A. SMITH, 1873).  
 1965. *Duplicaria concolor* (E. A. SMITH), R. BURCH, The Veliger, 7 (4): 251 (non *Terebra concolor* E. A. SMITH, 1873)

**Shell:** Shell small, moderately slender and shiny; cream to light fawn in colour ornamented with small irregular brown blotches and a narrow interrupted brown transverse band on whorls. Whorls convex, numbering about 16, apart from protoconch of 4 glassy violet nuclear whorls; presutural band defined by a deep and continuous spiral groove. Sculpture consists of broad, angulate, slightly curved and oblique axial ribs, numbering about 18 on the penultimate whorl; intercostal spaces smooth, faintly stained with orange-brown, early whorls coloured purple. Body whorl with a narrow white peripheral band, axial ribs becoming obsolete at this point; ultimate third of body whorl tan in colour and smooth. Columella white, centrally concave and corded, prominent outer cord joins margin at anterior canal which is slightly recurved; aperture elongate, whitish within.

**Size:** 34 mm.

**Habitat:** In clean sand, from 10 - 15 fathoms.

Rare.

**Distribution:** Mamanuca Group, West off Viti Levu. - ?

**Discussion:** This species is known from only one live-collected specimen which in colour, sculpture (smooth interstices) and size does not correspond with any known description. Collection of further material may help to establish the identity of this species.

44. *Duplicaria (Duplicaria)* *raphanula* (LAMARCK, 1822)

(Plate 6, Figure 46)

1822. *Terebra raphanula* LAMARCK, Anim. sans Vert., 7: 288  
 1909. *Terebra caledonica* SOWERBY, Proc. Malacol. Soc. London, 8 (4): 198, text fig.

**Shell:** Shell moderate in size, slender and solid; shining white or creamy-white in colour, ornamented with two spiral rows of orange or orange-brown blotches, those anterior to the sutures being the smaller. Whorls slightly convex, numbering from 10 to 13, apart from protoconch of 1½ to 2 white nuclear whorls; presutural band defined by a deep, obsolete punctate spiral groove. Sculpture consists of close-set and angulate axial ribs, numbering from 25 to 30 on the penultimate whorl; intercostal spaces smooth and concave, presutural band sparsely streaked with orange-brown. Body whorl with two narrow white transverse bands and three ill-defined transverse rows of orange blotches, ultimate row disappearing into aperture. Columella creamy-white, occasionally stained with orange, fairly broad, corded on inner margin, and with a prominent cord extending from columella to outer edge of the anterior canal; anterior canal straight, interior of aperture dark fawn or light orange-brown.

**Size:** 40 to 60 mm.

**Habitat:** In clean sand, in shallow water.

Rare.

**Distribution:** Southwest Viti Levu. - From South Africa through the tropical Indo-Pacific to Japan and the Fiji Islands.

45. *Duplicaria (Duplicaria)* *tiurensis* (SCHEPMAN, 1913)

(Plate 6, Figure 43)

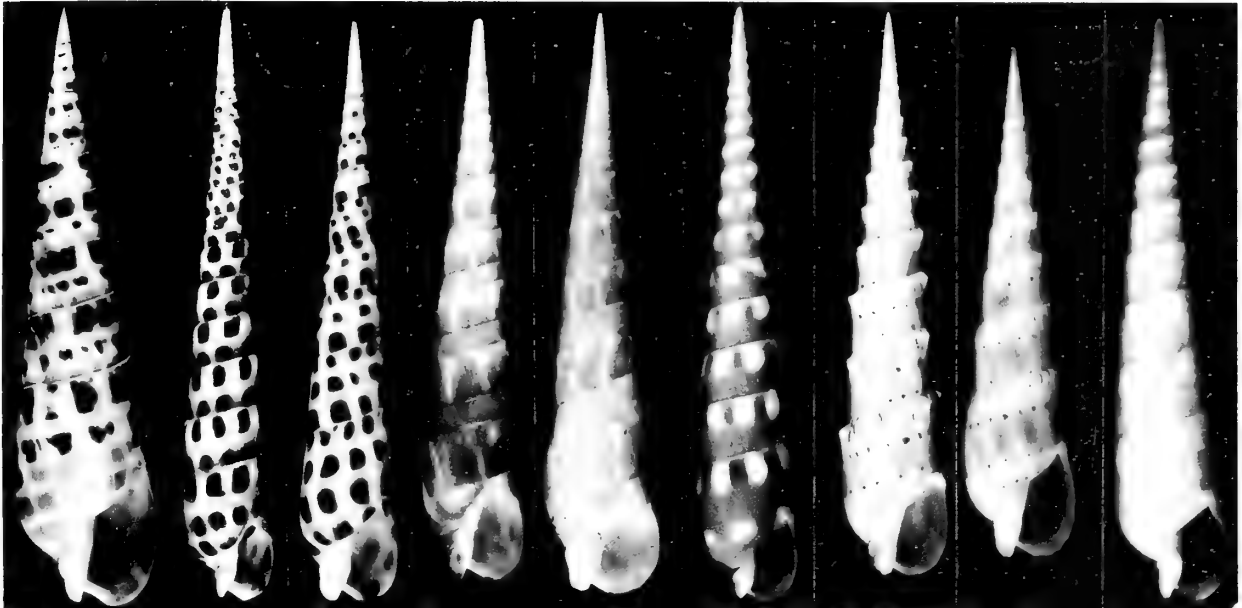
1913. *Terebra tiurensis* SCHEPMAN, Siboga Exp., Pt. 5, p. 374, pl. 25, fig. 10

**Shell:** Shell very small and fragile, slightly broadening towards aperture. Creamy-white in colour, ornamented with irregular chestnut-brown zones, axial streaks and spots. Whorls convex, numbering 12, apart from protoconch of 4 pinkish nuclear whorls; presutural band defined by a deep and narrow spiral groove. Sculpture consists of narrow, angulate and straight axial ribs, numbering about 21 on the penultimate whorl; the presutural groove forms small and narrow longitudinally oriented nodules at the sutures. Intercostal spaces with 4 to 5

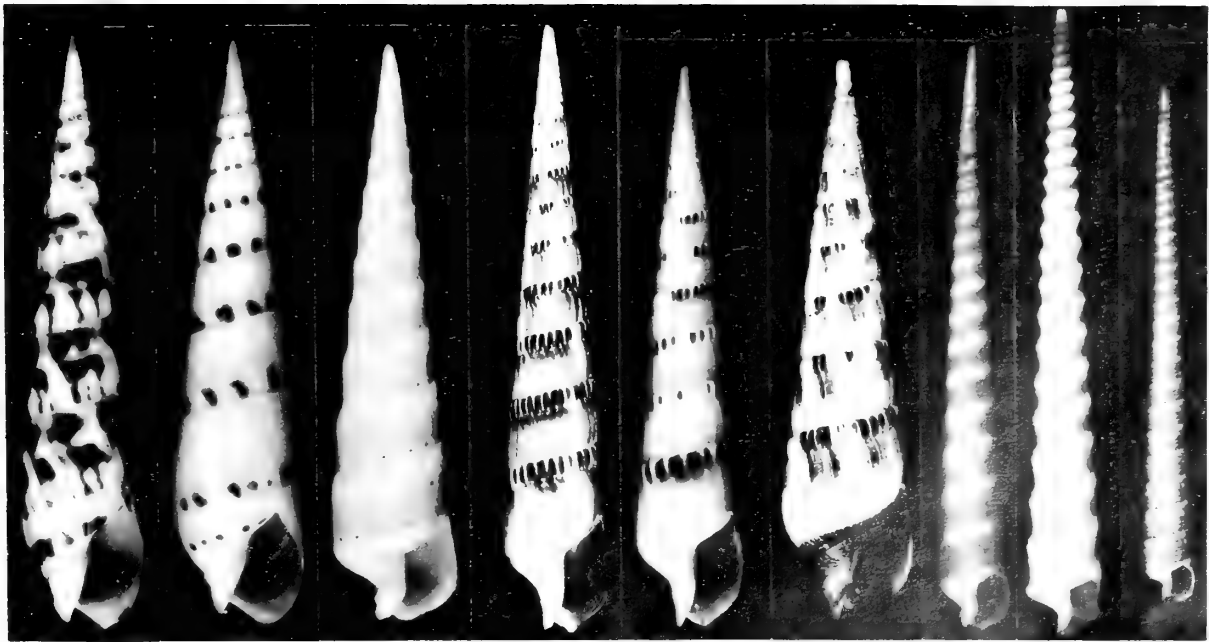
## Explanation of Plate 4

- Figure 1: *Terebra maculata* (LINNAEUS). Fiji. x 0.5  
 Figure 2: *Terebra subulata* (LINNAEUS). Fiji. x 0.7  
 Figure 3: *Terebra areolata* (LINK). Fiji. x 0.7  
 Figure 4: *Terebra dimidiata* (LINNAEUS). Fiji. x 0.7  
 Figure 4 a: *Terebra dimidiata* (LINNAEUS), variant. Fiji. x 0.7  
 Figure 5: *Terebra guttata* (RÖDING). Fiji. x 0.8  
 Figure 6: *Terebra crenulata* (LINNAEUS). Fiji. x 0.75  
 Figure 6 a: *T. crenulata* (LINNAEUS), smooth form. Fiji. x 0.8  
 Figure 7: *Terebra argus* HINDS. Fiji. x 1.0.

- Figure 8: *Terebra chlorata* LAMARCK. Fiji. x 1.2  
 Figure 9: *Terebra felina* (DILLWYN). Fiji. x 1.2  
 Figure 10: *Terebra succinea* HINDS. Fiji. x 1.0  
 Figure 11: *Terebra pertusa* (BORN). Fiji. x 1.25  
 Figure 11 a: *T. pertusa* (BORN), coarse-ribbed form. Fiji. x 1.3  
 Figure 12: *Terebra conspersa* HINDS. Fiji. x 2.0  
 Figure 13: *Terebra jenningsi* R. BURCH. Fiji. x 1.0  
 Figure 13 a: *T. jenningsi* R. BURCH, juvenile specimen. Fiji. x 1.75  
 Figure 14: *Terebra triseriata* GRAY. Fiji. x 0.8



1 2 3 4 4a 5 6 6a 7



8 9 10 11 11a 12 13 13a 14





very fine spiral striae. Body whorl slightly angulate, axially plicate, axial ribs becoming obsolete towards the anterior canal; a narrow whitish peripheral band encircles the body whorl, ultimate third of whorl light tan in colour. Columella creamy-white, concave, with a single cord extending towards the siphonal canal which is recurved; interior of aperture creamy-white.

Size: 18.7 mm.

Habitat: In clean sand, from 10 - 15 fathoms.

Rare.

Distribution: Momi Bay, West Viti Levu. - South Africa.

Discussion: The species is known from only one specimen and further material is needed to confirm the actual occurrence in Fiji.

*Hastula* H. & A. ADAMS, 1853

Type species: *Hastula concinna* (DILLWYN, 1817)

= *H. strigilata* (LINNAEUS, 1758)

#### 46. *Hastula alba* (MENKE, 1843)

(Plate 7, Figures 56, 56a)

1843. *Terebra alba* MENKE, Mollusc. Nov. Holl., p. 30  
 1844. *Terebra casta* HINDS, Proc. Zool. Soc. London for 1843: 156  
 1859. *Terebra incolor* DESHAYES, Proc. Zool. Soc. London, p. 283  
 1859. *Terebra bipartita* DESHAYES, Proc. Zool. Soc. London, p. 284  
 1859. *Terebra philippiana* DESHAYES, Proc. Zool. Soc. London, p. 289  
 1860. *Terebra aciculina* REEVE (pars), Conch. Icon., pl. 23, fig. 121a (non LAMARCK, 1822)  
 1903. *Hastula casta natalensis* E. A. SMITH, Proc. Malacol. Soc. London, 5 (6): 360  
 1921. *Terebra medipacifica* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 308, pl. 12, figs. 8, 9, 10  
 1921. *Terebra medipacifica melior* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 308, pl. 12, fig. 11

Shell: Shell small, slender and shiny; white or cream in colour throughout, occasionally ornamented with reddish-brown axial streaks and transverse bands. Whorls flat to slightly convex, numbering from 9 to 12, apart from protoconch of  $3\frac{1}{2}$  to  $4\frac{1}{2}$  glassy, reddish-brown or violet nuclear whorls; a presutural groove is absent. Sculpture consists of close-set rounded and oblique axial ribs, which are generally well defined near the sutures but obsolete on remainder of whorl; axial ribs number from 18 to 27 on the penultimate whorl, and rare individuals are axially ribbed from suture to suture. Body whorl axially plicate near suture but smooth on remainder of whorl, plain white or cream in colour, sometimes axially streaked with reddish-brown zones which are separated by a narrow white peripheral band. Columella centrally concave, corded on inner margin and with a fine cord extending

from the centre of the columella to the anterior canal; anterior canal thickened and straight, aperture elongate-ovate.

Size: 18 to 33 mm.

Habitat: In clean and silty sand, occasionally on weedy substrate, from 0 to 2 fathoms.

Uncommon.

Distribution: Throughout the Fiji Islands. - From Mauritius through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

Discussion: Specimens collected at Wading Island, Mamanuca group, are white or creamy-white throughout; those from Nadi Bay are dark and ornamented with reddish-brown. At Lomalagi, South Viti Levu, both forms occur in about equal numbers.

*Terebra alba* MENKE has priority over *T. casta* HINDS, since the Proceedings of the Zoological Society of London for 1843 were not published until 1844.

#### 47. *Hastula cernohorskyi* R. BURCH, 1965

(Plate 7, Figure 48)

1965. *Hastula (Punctoterebra) cernohorskyi* R. BURCH, The Veliger, 7 (4): 244 - 245, pl. 31, fig. 3

Shell: Shell moderate in size, heavy and moderately broad. Uniformly brown or olive-green in colour throughout, with an indistinct narrow flesh-coloured presutural band. Whorls flat to slightly convex, numbering from 9 to 14, apart from a very broad protoconch of 2 to  $2\frac{1}{2}$  glassy purplish nuclear whorls; presutural band defined by a spiral row of punctures in the interstices of the axial ribs. Sculpture consists of numerous close-set rounded axial ribs which become progressively shorter towards the penultimate whorl, and extend only up to one third of the whorl; axial ribs number from 36 to 51 on the penultimate whorl. Body whorl either obsoletely plicate or with slightly more distinct angulate and curved axial ribs which extend towards the anterior canal; one or two indistinct, light coloured transverse bands encircle the body whorl. Columella short, plicate, with a broad and flat flesh-coloured cord extending from the centre of the columella towards the anterior canal; anterior canal truncated, moderately broad and straight, stained with brown. Aperture oblong-ovate, lip reflected towards base.

Size: 37 to 60 mm.

Habitat: In clean sand, in shallow and possibly deeper water.

Rare.

Distribution: Southwest, West and East Viti Levu. - Philippine Islands?

**Discussion:** Subsequent to the description of the species by BURCH (1965), another 8 specimens devoid of animal were collected at Natadola (*leg.* A. Biddle, personal communication). All 16 specimens collected to date at Natadola had a portion about 10 mm in width of the outer lip broken off; some specimens regrew a part or the complete missing portion. The Natadola specimens ranged in size from 50 to 60 mm, while the only 2 live-collected specimens from Leleuvia Island (East off Viti Levu) and Lautoka, measured 37 and 43 mm respectively; it is interesting to note that the Lautoka specimen had the lip damaged and repaired.

The huge size of the protoconch in comparison with other *Hastula* or *Terebra* species is a rather salient feature of the species.

Paratype no. 3 of *Hastula cernohorskyi*, collected at Natadola by A. Morse, measuring 59.8 mm in length, has been deposited with the British Museum (Nat. Hist.) where it bears the register no. 1965142.

#### 48. *Hastula lanceata* (LINNAEUS, 1767)

(Plate 7, Figure 53)

1767. *Buccinum lanceatum* LINNAEUS, Syst. Nat., ed. 12, p. 1206  
1921. *Terebra lanceata oahuensis* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia, 69: 307

**Shell:** Shell moderately small and slender; shining white in colour, ornamented with 10 to 12 narrow, slightly waved dark reddish-brown longitudinal lines, which terminate anteriorly to the suture. Whorls flat, numbering from 15 to 18, apart from protoconch of 2 nuclear whorls; presutural groove absent. Generally smooth on last four whorls with early whorls axially plicate; occasional specimens, however, possess axial ribs as far as the penultimate whorl. Body whorl smooth, with the brown axial lines interrupted by a narrow white peripheral line. Columella

white, with a prominent raised cord on the outer margin; anterior canal straight, aperture elongate and white within. **Size:** 40 to 60 mm.

**Habitat:** In clean sand, from 0 - 5 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - From East Africa through the tropical Indo-Pacific to Polynesia and Hawaii.

**Discussion:** *Terebra lanceata oahuensis* described from Hawaii, has been separated solely on characters of axial plications. As axially ribbed forms occur sporadically in populations of *T. lanceata* from Fiji and Mauritius, *T. lanceata oahuensis* is regarded as an ecophenotypic variant only.

#### 49. *Hastula lauta* (PEASE, 1869)

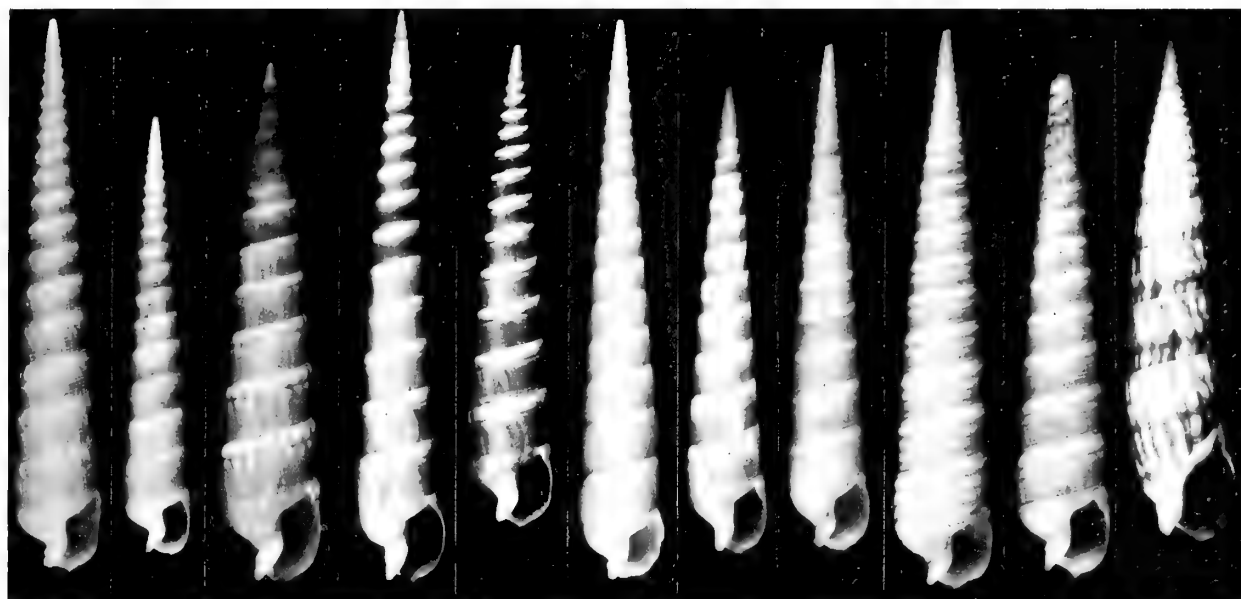
(Plate 7, Figure 51)

1869. *Terebra lauta* PEASE, Amer. Journ. Conch., 5: 66  
1925. *Terebra strigilata sumatrana* THIELE, Gastr. Deut. Tiefsee Exp., 17: 344, pl. 29, fig. 20

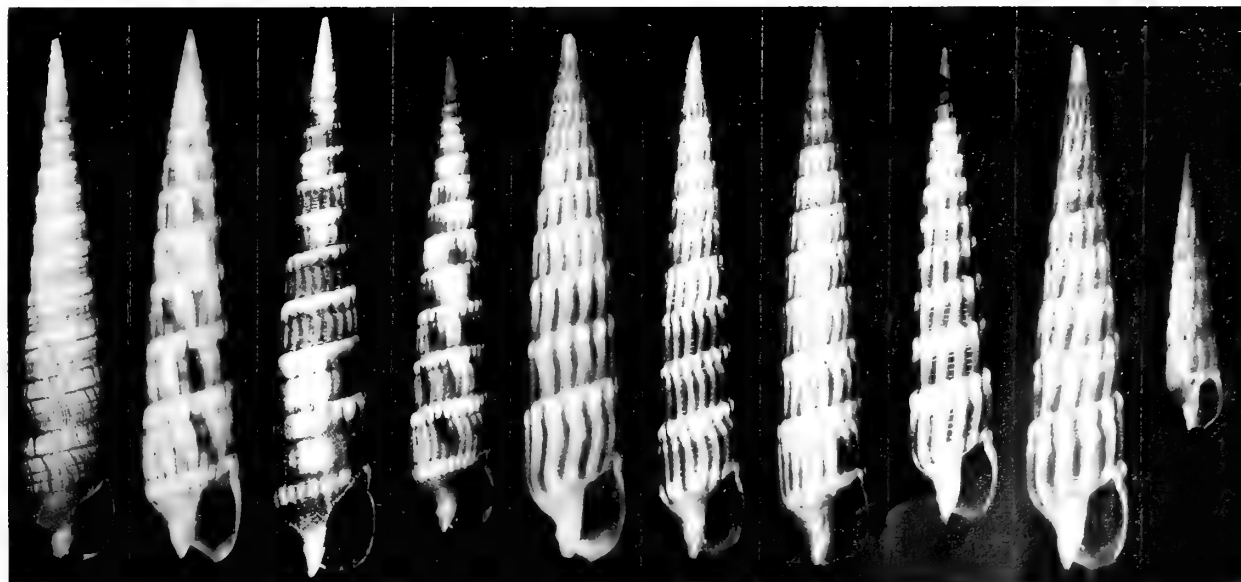
**Shell:** Shell small and slender; dark grey to greenish-grey in colour, ornamented with blackish-brown somewhat squarish small spots at the sutures, and irregular intervening white spots. Whorls flat or slightly convex, numbering from 11 to 13, apart from protoconch of 3 to 3½ glassy, light tan nuclear whorls; presutural band defined by a narrow deep spiral groove which is confined to the interstices and extends only a short way onto the walls of the axial ribs. Sculpture consists of straight narrow angulate and wide-spaced axial ribs, numbering from 14 to 17 on the penultimate whorl. Body whorl with a narrow white peripheral band, axial ribs becoming obsolete at this point; area near anterior canal white. Columella dark brown, corded on interior margin, with a calloused area extending onto the body whorl; margins of callus corded

### Explanation of Plate 5

- Figure 15: *Terebra anilis* (RÖDING). Fiji. x 1.8  
Figure 16: *Terebra* species. Fiji. x 1.2  
Figure 17: *Terebra amanda* HINDS. Fiji. x 1.75  
Figure 18: *Terebra cingulifera* LAMARCK. Fiji. x 1.1  
Figure 18a: *T. cingulifera* LAMARCK (forma *albomarginata* DESHAYES). Fiji. x 1.2  
Figure 19: *Terebra pallida* DESHAYES. Fiji. x 0.7  
Figure 20: *Terebra montgomeryi* R. BURCH, Hypotype no. 1. Fiji. x 1.25  
Figure 21: *Terebra laevigata* GRAY. Fiji. x 1.5  
Figure 22: *Terebra funiculata* HINDS. Fiji. x 2.0  
Figure 23: *Terebra langfordi* PILSBRY. Fiji. x 1.6  
Figure 24: *Terebra cerithina* LAMARCK. Fiji. x 1.0  
Figure 25: *Terebra babylonia* LAMARCK. Fiji. x 1.0  
Figure 26: *Terebra affinis* GRAY. Fiji. x 1.2  
Figure 27: *Terebra nebulosa* SOWERBY. Fiji. x 1.0  
Figure 28: *Terebra columellaris* HINDS. Fiji. x 1.6  
Figure 29: *Terebra undulata* GRAY. Fiji. x 2.0  
Figure 30: *Terebra* (*Decorihastula*) species. Fiji. x 2.0  
Figure 31: *Terebra paucistriata* (E. A. SMITH). Fiji. x 2.3  
Figure 31a: *T. paucistriata* (E. A. SMITH). Holotype no. B. M. N. H. 1856.11.3.17. Ovalau, Fiji Islands. Length 18.5 mm. Photo British Museum (Natural History).



15 16 17 18 18a 19 20 21 22 23 24



25 26 27 28 29 30 31 31a



and elevated, extending to the anterior canal; aperture convexly rounded, interior dark brown.

**Size:** 22 to 26 mm.

**Habitat:** In muddy sand, on weedy substrate, in shallow and deeper water.

**Rare:**

**Distribution:** West Viti Levu. – From the Philippine Islands through the tropical Pacific to the Hawaiian Islands.

**Discussion:** The species has been reported as endemic to the Hawaiian Islands in literature. Reliable records besides Fiji are from the Philippine Islands, New Guinea and West Australia.

#### 50. *Hastula penicillata* (HINDS, 1844)

(Plate 7, Figures 54, 54 a, 54 b, 54 c)

1839. *Terebra lanceata* KIENER (pars), Spéc. Gén. Icon. Coq. Viv., pl. 10, figs. 22 a, 22 b (non *Buccinum lanceatum* LINNAEUS, 1767)

1844. *Terebra penicillata* HINDS, Proc. Zool. Soc. London for 1843: 157

1844. *Terebra venosa* HINDS, Proc. Zool. Soc. London for 1843: p. 157

1859. *Terebra crossi* DESHAYES, Proc. Zool. Soc. London, p. 289

1965. *Hastula (Punctoterebra) betsyae* R. BURCH, The Veliger, 7 (4): 243, pl. 31, fig. 2

**Shell:** Shell small, moderately slender and solid; variable in colour, but generally ivory-white or cream, ornamented with irregular golden-brown wavy longitudinal lines, extending across the whole width of the whorl; occasional specimens have deep chocolate-brown longitudinal lines and broad transverse bands of the same colour. Whorls flat to slightly convex, numbering from 11 to 15, apart from protoconch of 2 to 3 glassy whitish nuclear whorls; whorls generally smooth; however, occasional individuals have a single spiral line of punctures, situated about one third the width of the whorl anteriorly to the suture. Sculpture consists of somewhat angulate axial ribs on the early whorls, ribs becoming generally obsolete on the last 3 to 4 whorls, and only visible at sutures; occasional specimens, however, are plicate even on the penultimate whorl. Body whorl long and generally smooth, axially lined with golden-brown or blotched on occasions with chocolate-brown. Columella white, sharply corded exteriorly; aperture elongate-ovate, white within, anterior canal straight.

**Radula (punctate form):** Radular ribbon translucent white, 1.7 mm long and 0.012 mm wide in animal with a shell 39 mm in length; fully-formed rows numbered 37 and teeth in the first three front rows were shorter than

others. Radular teeth consist of a pair of slender and curved teeth which lack accessory cusps or hooks.

**Size:** 23 to 40 mm.

**Habitat:** In clean and silty sand, occasionally on weedy substrate, from 0 to 2 fathoms.

**Uncommon.**

**Distribution:** Throughout the Fiji Islands. – From East Africa through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

**Discussion:** The dark chocolate-brown form has been described as *Terebra venosa* HINDS; this form occurs in the Fiji Islands, and we have also seen specimens from Mauritius (leg. E. Couacaud); it has also been figured by C. WEAVER (1960) from the Hawaiian Islands.

The form of *Hastula penicillata* sculptured with a single

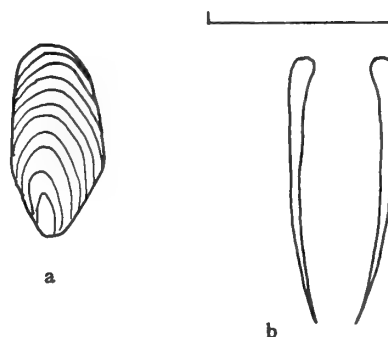


Figure 13

*Hastula penicillata* (HINDS) (punctate form)  
a – Operculum      b – One row of radular teeth

row of pits on the whorls has also been collected in Fiji; it is sympatric with the smooth form in South and South-west Viti Levu. It is interesting to note, however, that all three forms of *H. penicillata* are found together only in silty-sand and weedy localities in Fiji, while only the "typical" smooth, light-coloured form is found in clean sand environment. The senior author collected the smooth form and the spirally punctate form in the same dredge haul from one square yard; an examination of the animals and radulae of both forms did not reveal any differences. The mitrid species *Imbricaria olivaeformis* (SWAINSON, 1821) also occurs either smooth or with spiral rows of punctures in populations of the species in Fiji and the Hawaiian Islands; in Fiji, however, the sculptured form is more prevalent in silty-sand locations.

51. *Hastula plumbea* (QUOY & GAIMARD, 1832)

(Plate 7, Figure 52)

1832. *Terebra plumbea* QUOY & GAIMARD, Voy. Astrol., p. 470, pl. 36, figs. 29, 30  
 1859. *Terebra bourguignati* DESHAYES, Proc. Zool. Soc. London, p. 288, no. 66  
 1898. *Terebra celidonta* MELVILL & SYKES, Proc. Malacol. Soc. London, 3 (1): 42, pl. 3, fig. 2  
 1952. *Terebra hoffmayeri* ABBOTT, Nautilus, 65 (3): 78, pl. 5, figs. 5-9

**Shell:** Shell small and slender; greyish-brown to blackish-brown in colour, ornamented with a narrow whitish or fawn transverse presutural band. Whorls slightly convex, numbering from 10 to 12, apart from 2 glassy nuclear whorls. Sculpture consists of sharply angulate almost straight axial ribs; numbering from 13 to 15 on the penultimate whorl; intercostal spaces smooth, except for fine, almost obsolete spiral striae situated on the walls of the axial ribs and almost reaching the apex. Body whorl axially plicate, with a light transverse band situated posteriorly to the columella. Columella brown, prominently corded and with a raised, slightly calloused area extending onto the body whorl; anterior canal recurved, interior of aperture dark brown.

**Size:** 13 to 24 mm.

**Habitat:** In muddy and weedy sand, from 0 to 5 fathoms.

Rare.

**Distribution:** West Viti Levu. – Throughout the Pacific Ocean to the Hawaiian Islands.

52. *Hastula solida* (DESHAYES, 1857)

(Plate 7, Figure 55)

1791. *Buccinum aciculatum* GMELIN, Syst. Nat., ed. 13, p. 3503 (non LAMARCK, 1822) [*nomen oblitum*]

1857. *Terebra solida* DESHAYES, Journ. Conchyl., 6: 78, pl. 3, fig. 11

1912. *Terebra clarkei* H. SMITH, Nautilus, 26 (6): 75, pl. 4, fig. 18

**Shell:** Shell small and solid, broadening towards aperture; white in colour, ornamented with a narrow cream or light fawn transverse band on whorl. Whorls flat to slightly convex, shouldered at sutures in certain individuals, numbering from 9 to 12, apart from protoconch of  $2\frac{1}{2}$  to 3 light orange nuclear whorls. Sculpture consists of straight or only slightly curved broad flattish close-set axial ribs, numbering from 14 to 18 on the penultimate whorl; intercostal spaces smooth and narrow, often stained with orange. Body whorl axially plicate, with three narrow light fawn transverse bands, ultimate band entering aperture. Columella whitish in colour, wide, centrally concave, with an orange spiral cord interiorly and a rounded white or orange cord on the exterior margin; anterior canal straight, aperture elongate, whitish within.

**Size:** 20 to 28 mm.

**Habitat:** In clean and slightly muddy sand, from 0-3 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands through the tropical Pacific to Polynesia and Hawaii.

**Discussion:** GMELIN (1791) referred to CHEMNITZ (1780, vol. 4, pl. 155, fig. 1457) for his *Buccinum aciculatum*; the figure cited is a fair representation of *Hastula solida* (DESHAYES). GMELIN, however, mentioned "excavated punctures" in his description, a feature incompatible with *H. solida*. GMELIN's name, however, should be regarded as a *nomen oblitum* according to article 23b of the Code of the I. C. Z. N. (1961), since it has not been in use in the last 50 years. GMELIN's specific name, however, pre-occupies *Buccinum aciculatum* LAMARCK, 1822, which is a columbellid.

## Explanation of Plate 6

- Figure 32: *Terebra kilburni* R. BURCH. Paratype no. 1, Wading Island, Fiji Islands (slender form). x 2.0  
 Figure 32 a: *T. kilburni* R. BURCH. Paratype no. 16, Lomalagi, Fiji Islands (obese form). x 3.0  
 Figure 33: *Terebra succincta* (GMELIN). Fiji. x 2.0  
 Figure 34: *Terebra flavescens* DESHAYES. Fiji. x 2.0  
 Figure 35: *Terebra flavofasciata* PILSBRY. Fiji. x 2.0  
 Figure 36: *Terebra textilis* HINDS. Fiji. x 2.0  
 Figure 37: *Terebra fenestrata* HINDS. Fiji. x 2.5  
 Figure 38: *Terebra exigua* DESHAYES. Fiji. x 2.5  
 Figure 39: *Terebra multistriata* SCHEPMAN. Fiji. x 3.0  
 Figure 40: *Terebra turrita* E. A. SMITH. Fiji. x 3.0  
 Figure 40 a: *T. turrita* E. A. SMITH. Fiji. x 3.0  
 Figure 40 b: *T. turrita* E. A. SMITH. Holotype no. B. M. N. H.

1965137 ex Cuning Coll. Length 23.0 mm. Photo British Museum (Natural History)

Figure 41: *Terebra* (*Clathroterebra*) species. Fiji. x 3.0

Figure 42: *Terebra fijiensis* E. A. SMITH. Holotype no. B. M. N. H. 1856.10.27.8. Ovalau, Fiji Islands. Length 19.8 mm. Photo British Museum (Natural History)

Figure 43: *Duplicaria tiurensis* (SCHEPMAN). Fiji. x 3.0

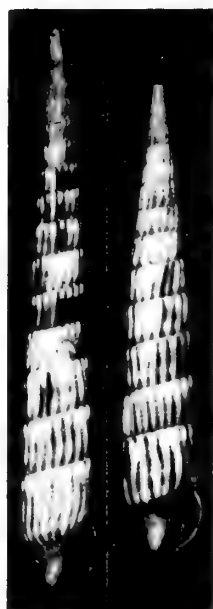
Figure 44: *Duplicaria* species. Fiji. x 1.7

Figure 45: *Duplicaria concolor* (E. A. SMITH). Lectotype no. B. M. N. H. 1965136. Length 22.0 mm. Photo British Museum (Natural History)

Figure 46: *Decorihastula raphanula* (LAMARCK). Fiji. x 1.4

Figure 47: *Impages hectica* (LINNAEUS). Fiji. x 1.1

Figure 47 a: *I. hectica* (LINNAEUS). Fiji (axially striate variant). x 1.1

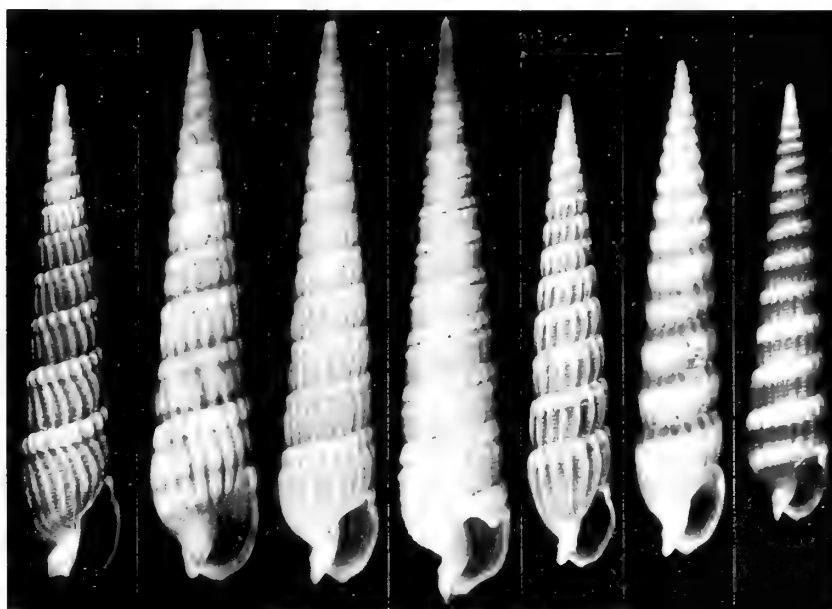


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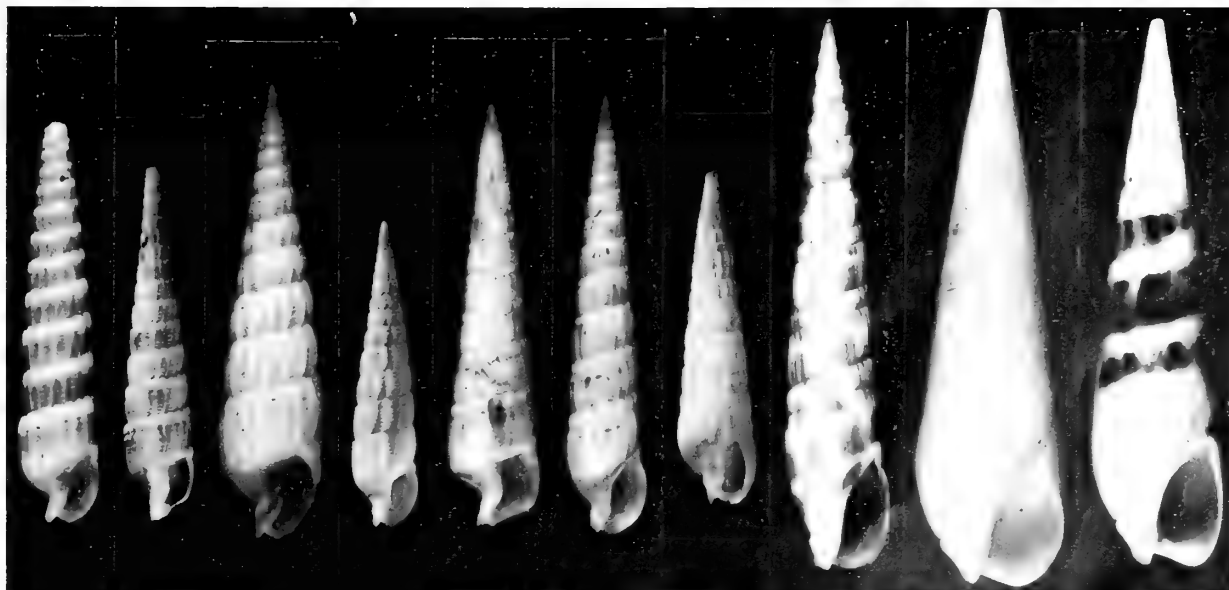
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40 b

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53. *Hastula strigilata* (LINNAEUS, 1758)

(Plate 7, Figure 50)

1758. *Buccinum strigilatum* LINNAEUS, Syst. Nat., ed. 10., p. 741, no. 418 (GUALTIERI, 1742, pl. 57, fig. O)  
 1767. *Buccinum strigilatum* LINNAEUS (pars), Syst. Nat., ed. 12, p. 1306, no. 484 (ARGENVILLE, 1742, pl. 14, fig. R only)  
 1798. *Epitonium acutissimum* RÖDING, Mus. Bolten., p. 95  
 1802. *Terebra strigillata* BOSCH, Hist. Nat. Coq., 5: p. 15  
 1817. *Buccinum concinnum* DILLWYN (pars), Desc. cat. rec. shells, 2: 647 (non C. B. ADAMS, 1845 = Columbelloid)  
 1829. *Terebra strigillosa* BLAINVILLE, Dict. Sci. Nat., 58: 285  
 1830. *Terebra myurus* MENKE, Synop. meth. Mollusc., p. 84  
 1839. *Terebra striatula* KIENER (pars), Spéc. Gén. Icon. Coq. Viv., pl. 9, fig. 18 (non LAMARCK, 1822)  
 1857. *Terebra verreauxi* DESHAYES, Journ. Conchyl., 6: 95, pl. 5, fig. 3  
 1859. *Terebra argenvillei* DESHAYES, Proc. Zool. Soc. London, p. 286  
 1859. *Terebra acumen* DESHAYES, Proc. Zool. Soc. London, p. 287  
 1859. *Terebra modesta* DESHAYES, Proc. Zool. Soc. London, p. 288  
 1925. *Terebra strigilata gracilior* THIELE, Gast. Deutsche Tiefs. Exped., 17: 344, pl. 29, fig. 19

**Shell:** Shell small, moderately slender and shiny; dark grey or greenish-grey in colour, ornamented with blackish-brown, squarish to rhomboidal blotches on a white presutural band. Whorls slightly convex, numbering from 10 to 15, apart from protoconch of 3 glassy-brown nuclear whorls. Sculpture consists of close-set broad and flat obliquely oriented axial ribs; intercostal spaces defined as very narrow smooth longitudinal grooves. Body whorl axially plicate, with a narrow white peripheral band. Columella centrally concave, interior half dark brown, exterior white, with a brown cord extending from centre of columella to the outer margin of the anterior canal; anterior canal straight, interior of aperture dark grey.

**Size:** 21 to 32 mm.

**Habitat:** In muddy sand, on weedy substrate, in shallow and deeper water.

**Uncommon.**

**Distribution:** South and West Viti Levu. – From the Philippine Islands through the tropical Pacific to Polynesia and Hawaii.

**Discussion:** *Hastula lauta* (PEASE) is very similar in colour pattern to *H. strigilata*, but differs mainly in having wide-spaced and angulate axial ribs and a presutural spiral groove; the ultimate half of the body whorl is smooth in *H. lauta*, but axially ribbed in *H. strigilata*.

LINNAEUS' original description "*B. testa turrita oblique striata*" is applicable to a number of similar species with axial sculpture, and is in direct conflict with the single reference cited from RUMPHIUS (1705, pl. 30, fig. H), which does not represent *Hastula strigilata* of authors. In

the 12th edition of the "Systema Naturae," the unenlightening words "*anfractibus bifidis*" and three references to figures were added. One of these figures (BUONANNI, 1604, fig. 110) represents *Terebra duplicata* (LINNAEUS), and was deleted by LINNAEUS in a manuscript note (*vide* DODGE, 1956). The remaining two references (GUALTIERI, 1742, pl. 57, fig. O, and ARGENVILLE, 1742, pl. 14, fig. R) are entirely correct and represent *Hastula strigilata* of authors. Thus, the original definition of *H. strigilata* is equivocal, while the revised description of the 12th edition of the "Systema Naturae" is correct after the deletion of the BUONANNI figure by LINNAEUS in his manuscript.

The *Hastula strigilata* of BORN (1780, pl. 10, fig. 10) is conceded to be the *H. strigilata* of authors by most authors. BORN, however, clearly associated his own *H. strigilata* with that of LINNAEUS by repeating three LINNAEAN references for the species. In such dubious interpretations of a taxon as *H. strigilata*, taxonomic validity of interpretation by the first subsequent revisor should be acknowledged, which in this case means LINNAEUS himself (1767) or BORN (1780).

The CHEMNITZ figures cited by GMELIN (1791) for his *Buccinum commaculatum* (CHEMNITZ, 1780, pl. 154, fig. 1452) appears to depict a species of the family Turritellidae.

54. *Hastula stylata* (HINDS, 1844)

(Plate 7, Figure 49)

1844. *Terebra stylata* HINDS, Proc. Zool. Soc. London for 1843: 152

**Shell:** Shell moderately small, broadening towards the aperture; light fawn to brown in colour, ornamented with dark brown irregular short axial streaks at the sutures; axial streaks occasionally coalesce and form a narrow irregular presutural band. Whorls flat, numbering about 10, apart from protoconch of 2 whitish nuclear whorls; a presutural groove is absent. Sculpture consists of narrow angulate and slightly curved axial ribs, ribs becoming obsolete a short distance posteriorly to the sutures; intercostal spaces smooth, sutures generally a light flesh colour. Body whorl obsoletely plicate, with a narrow white peripheral band which is followed by a slightly broader dark brown band; base of shell whitish, with occasional specimens having ill-defined small brown blotches on body whorl. Columella short, concave, with a cord on the inner margin; a moderately thick angulate cord extends from the centre of the columella to the anterior canal. Anterior canal short, truncate, moderately broad, straight, stained with brown; aperture very broad and flaring, reflexed

near the base; interior of aperture brown with a narrow white band.

Size: 32 to 39 mm.

Habitat: Unknown. Dead specimens dredged in sand in shallow water.

Rare.

Distribution: Southwest Viti Levu. – From the Philippine Islands to Japan and Fiji.

### *Impages* E. A. SMITH, 1873

Type species: *Terebra caerulea* LAMARCK, 1822  
= *Impages hectica* (LINNAEUS, 1758)

#### 55. *Impages hectica* (LINNAEUS, 1758)

(Plate 6, Figures 47, 47 a)

1758. *Buccinum hectica* LINNAEUS, Syst. Nat., ed. 10, p. 741 (GUALTIERI, 1742, pl. 56, fig. C)  
1791. *Buccinum niveum* GMELIN, Syst. Nat., ed. 13, p. 3504 (non GMELIN, 1791, p. 3471 and 3495)  
1791. *Buccinum edentulum* GMELIN, Syst. Nat., ed. 13, p. 3505  
1817. *Buccinum bifasciatum* DILLWYN, Descr. cat. rec. shells, 2: p. 651  
1822. *Terebra caerulea* LAMARCK, Anim. sans Vert., 7: 288  
1828. *Buccinum terebrale* MENKE, Synop. Mollusc., p. 84  
1830. *Terebra caerulea* var. *otaitensis* LESSON, Voy. Coq., 2 (1): 407  
1844. *Terebra nimboza* HINDS, Proc. Zool. Soc. London for 1843: p. 151  
1880. *Terebra flammulata* VON MARTENS, Mauritius, p. 230, pl. 20, fig. 5  
1935. *Terebra (Impages) hectica* var. *alba* DAUTZENBERG, Mém. Mus. Roy. Hist. Nat. Belg. 2 (17): 42, pl. 2, fig. 4  
1935. *Terebra (Impages) hectica* var. *fusca* DAUTZENBERG, Mém. Mus. Roy. Hist. Nat. Belg., 2 (17): 42, pl. 2, fig. 2 (non PERRY, 1811)

Shell: Shell medium in size, heavy and solid, broadening towards aperture; shining white or creamy-white in colour, sparsely mottled with purplish-brown, markings arranged in axial streaks or an interrupted transverse band; occa-

sional specimens pure white. Whorls flat, rarely slightly concave, smooth, numbering from 14 to 17, apart from protoconch; presutural band weakly defined, sutures weakly impressed. A narrow, slightly elevated spiral callosity is situated posteriorly to the sutures, whorls with fine and close-set axially curved growth striae; early whorls obsoletely axially plicate. Columella creamy-white, broad and flat, corded on inner margin; a prominent rounded cord extends from columella to siphonal canal; interior of aperture white.

Size: 45 to 75 mm.

Habitat: In fine clean sand and sand-pockets of coral reefs. Rare.

Distribution: Throughout the Fiji Islands. – From the Red Sea through the tropical Indo-Pacific to Polynesia and Hawaii.

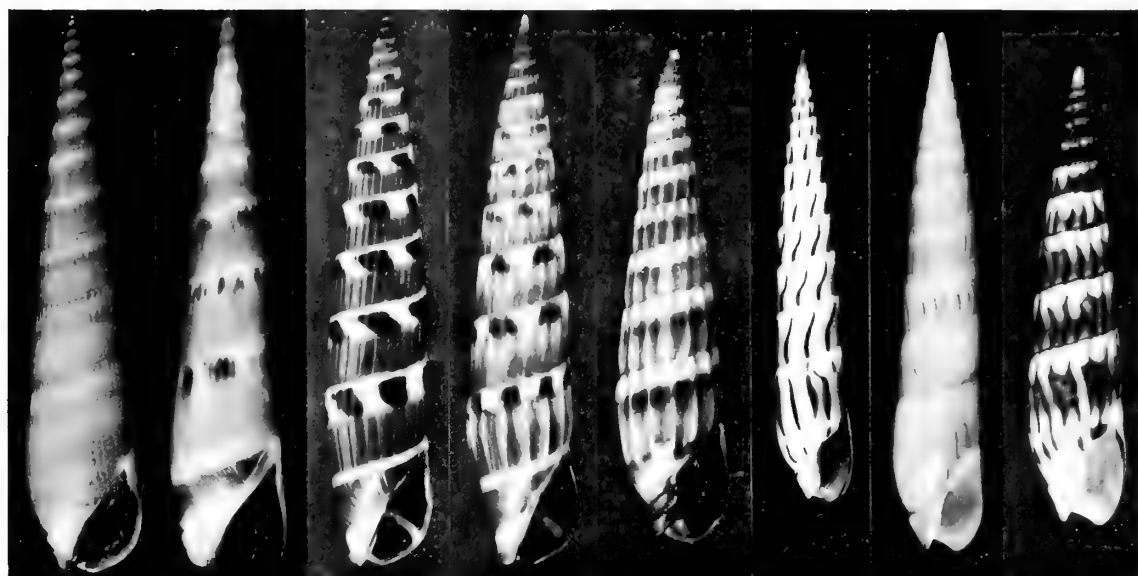
Discussion: The sutures of the whorls are, in most specimens, almost obsolete, but visible with the naked eye in others; although generally smooth, some specimens have the protraxially curved growth striae slightly elevated, giving the shell an axially ribbed effect.

DODGE (1956) advocated a suppression of the LINNAEUS *Buccinum hecticum*, since according to the writer the species is not clearly defined. Very few of LINNAEUS' species of mollusca are unequivocally defined and quite a number of species are composite species with a conflicting synonymy. LINNAEUS' original 10th edition of the "Systema Naturae" description: "*B. testa turrita, anfractibus margine superiore compresso-attenuato*" is apt, and too short to be faulted; the single reference to GUALTIERI (1742, pl. 56, fig. C) is indeed the same species as *Terebra caerulea* LAMARCK, a name adopted by recent writers and the *Hastula hectica* of authors. The GUALTIERI delineation (op. cit.) has been recognized as representing *H. hectica* of authors by DESHAYES & MILNE-EDWARDS (1835-1845), DAUTZENBERG (1935) and DODGE (1956). Confusion as to the true identity of *H. hectica* arose in the 12th edition of the "Systema Naturae," where the words "*anfractibus bifidis*" and a reference to SEBA (1758, pl.

### Explanation of Plate 7

- Figure 48: *Hastula cernohorskyi* R. BURCH. Paratype no. 1, Natadola, Fiji Islands. x 1.3  
Figure 49: *Hastula stylata* (HINDS). Fiji. x 2.0  
Figure 50: *Hastula strigilata* (LINNAEUS). Fiji. x 2.5  
Figure 51: *Hastula lauta* (PEASE). Fiji. x 3.0  
Figure 52: *Hastula plumbea* (QUOY & GAIMARD). Fiji. x 3.0  
Figure 53: *Hastula lanceata* (LINNAEUS). Fiji. x 1.0  
Figure 54: *Hastula penicillata* (HINDS). Fiji. x 1.7

- Figure 54 a: *H. penicillata* (HINDS), forma *venosa* HINDS. Fiji. x 2.2  
Figure 54 b: *H. penicillata* (HINDS), spirally punctate form. Fiji. x 2.0  
Figure 54 c: *H. penicillata* (HINDS). Magnified view showing spiral punctures. x 6.0  
Figure 55: *Hastula solida* (DESHAYES). Fiji. x 2.8  
Figure 56: *Hastula albula* (MENKE), white form. Fiji. x 2.1  
Figure 56 a: *H. albula* (MENKE), banded form. Fiji. x 2.5



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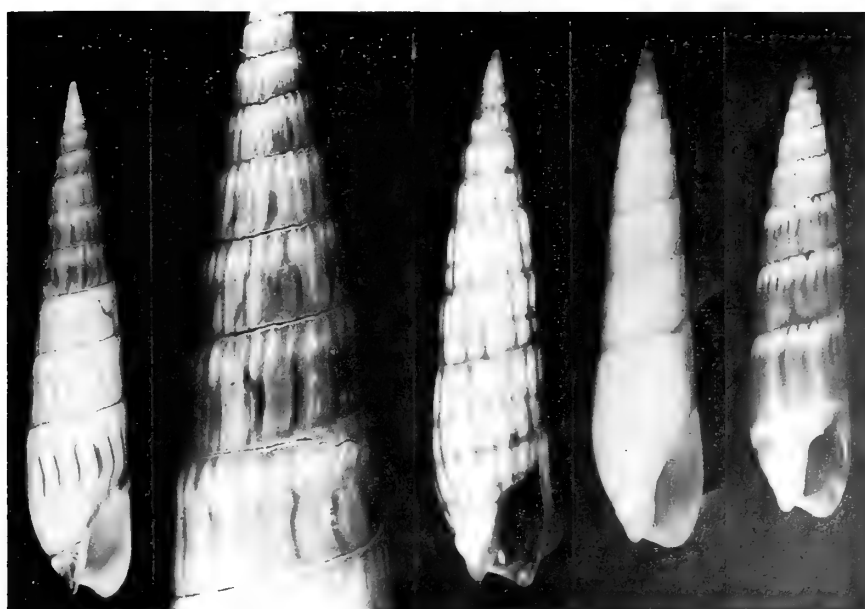
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54 a



54 b

54 c

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56 a



56, fig. 21) were added. This particular figure represents *Buccinum crenulatum* LINNAEUS and may have been a transposition for figure 35 on the same plate, which represents *B. hecticum* and was cited for the species *B. crenulatum* by LINNAEUS. It appears illogical to suppress *Hastula hectica* which is fairly clearly defined by the original 10th edition "Systema Naturae" description, and accept *Terebra dimidiata* (LINNAEUS) which is not only equivocal but consists of an entirely erroneous synonymy.

The diacritic mark in the original spelling of "*Buccinum hecticū*" occurs in several specific names appearing in the 10th edition of the "Systema Naturae" (1758), i. e. *Conus spectrū*, *Murex oleariū*, *Dentalium minutū* and several others. It appears that in preference to having a single letter of the same specific name stand in the second line, the diacritic mark was used by the printer to indicate the appropriate one-letter termination of the specific name.

#### TEREBRIDAE REPORTED FROM THE FIJI ISLANDS BY J. CATE AND R. BURCH, 1964

*Terebra albicostata* ADAMS & REEVE, 1850: The specimen reported from Fiji under this name is actually a specimen of *Terebra dislocata* (SAY, 1822), and was acquired by the junior author from another Fiji collector with a Fiji locality label. The specimen probably reached Fiji from Florida or the West Indies through exchange channels.

*Terebra anilis* (RÖDING, 1798): Specimens reported under this name from the Fiji Islands are listed here as *Terebra* (*Perirhoe*) species.

*Terebra archimedes* [sic] DESHAYES, 1859: Specimens identified as *T. archimedis* are *T. laevigata* GRAY, 1834. DESHAYES (1859) described his species as possessing three presutural spiral cords, whereas only two spiral cords are present in *T. laevigata*.

*Terebra cumingi* DESHAYES, 1857: We believe this to be *T. anilis* (RÖDING). *Terebra cumingi* was described as white or pale yellowish in colour, almost four inches in length, with 30 whorls and elegantly sculptured axial ribs. Fiji specimens are chestnut or reddish-brown, with a maximum of 20 whorls, growth striae instead of axial ribs, and specimens never exceed two inches in length. TOMLIN (1944) examined the type of *T. cumingi* in the British Museum, and found the species to be very near to *T. triseriata* GRAY and *T. lima* DESHAYES. The CHEMNITZ figure cited for *T. anilis* by RÖDING (1780, vol. 4, pl. 155, fig. 1456) does not appear to differ from specimens reported as *T. cumingi* from Fiji.

*Terebra paucistriata* (E. A. SMITH, 1873): Specimens of this species are not conspecific with the *T. paucistriata* of SMITH. They are listed here as *Terebra* (*Decorihastula*) species.

*Terebra polygyrata* DESHAYES, 1859: Specimens reported under this name from Fiji are *T. turrita* (E. A. SMITH, 1873).

*Terebra turrita* (E. A. SMITH, 1873): This is not SMITH's species, but the only specimen reported from Fiji under this specific name appears to be a small juvenile beach specimen of *T. pertusa* (BORN).

*Terebra violascens* HINDS, 1844: This single specimen from Fiji bears no resemblance to HINDS' type-figure; it is reported here as *Terebra* (*Clathroterebra*) species.

*Duplicaria australis* (E. A. SMITH, 1873): This specimen is not SMITH's *D. australis* and is reported here as *Duplicaria* species.

#### TEREBRIDAE REPORTED FROM THE FIJI ISLANDS BY R. BURCH, 1965

*Terebra fijiensis* (E. A. SMITH, 1873): SMITH's holotype represents a species which is unknown in Fijian collections. *Terebra marmorata* DESHAYES, 1859: The only specimen from Fiji is a small, juvenile beach specimen of *T. pertusa* (BORN). DESHAYES' original description of *T. marmorata* is similar to the species *T. amoena* DESHAYES, 1859, and TOMLIN (1944) reports both holotypes to be identical.

*Duplicaria concolor* (E. A. SMITH, 1873): This species was previously reported as *D. australis* (E. A. SMITH, 1873) by J. CATE & BURCH (1964). SMITH's holotype represents a different species, and the Fiji shell is here simply listed as *Duplicaria* species.

#### FOSSIL RECORDS OF TEREBRIDAE FROM THE FIJI ISLANDS

*Terebra* (*Strioterebrum*) species; LADD, Bernice P. Bishop Mus. Bull. 119: 233, pl. 41, fig. 9: The species was described but not named, from Pleistocene deposits on the banks of the Wailoa River near Nasogo, at an elevation of 995 feet. The species does not resemble any of the Recent Fijian Terebridae.

#### CONCLUSION

A total of 55 species of Terebridae have been recorded from Recent collections in the Fiji Islands (*Terebra fijiensis* HINDS excepted).

The numbers of species recorded in the appropriate genera are:

<i>Terebra</i>	42
<i>Duplicaria</i>	3
<i>Hastula</i>	9
<i>Impages</i>	1
Total	55

The 55 species recorded represent approximately 30% to 35% of all known Recent terebrid species. It is expected that further collecting and dredging will add new records to the terebrid fauna of the Fiji Islands.

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## Elevation of Clams in Coral Sand

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ARMSTRONG (1965) HAS FOUND that some clams of the larger species with long, extensible siphons, do not seem to be able to elevate, or come up through the sand. His experiments included covering the clams with additional sand from their environment. Until a critical amount {four inches of additional sand for *Tresus nuttalli* (CONRAD, 1837), three inches for *Protothaca staminea* (CONRAD, 1837)} was added, the clams could extend their siphons and/or maintain a conical depression in the surface of the sand, and survive. At this critical level all clams succumbed. Removal and redeposition of sand did not kill the clams, so that it was not just 'suffocation' from the disturbed sand that caused the deaths, but the inability of the clams to elevate through the sand or to extend their siphons.

It is known that clams are less dense than their environment. ARMSTRONG's clams average 1.21 to 2.04 in specific gravity (gm/cc), while local inorganic sands average 3.00. The average of the ten species tested was 1.46 gm/cc, less than half that of the sand. The effect of this difference in specific gravity would be to cause the clams to be buoyant in the sand, and any motion on their part would tend to lift them up through the sand. Thus, their main efforts in areas of sand agitation through surf action would be to remain submerged, and their capabilities are morphologically and physiologically directed

toward this end. If wave action is not sufficient to disturb the sand sufficiently to elevate the clams, it would be possible for them to 'shake' themselves and elevate to a limited extent, provided that they are not buried too deeply or the sand is not too compact. The tendency for the relatively fine sand to be sifted under larger objects would also cause sand agitation to effectively lift the clams out of the sand. The application of this buoyancy and sifting effect can be readily seen by shaking a container with sand and clams, where one will see the latter lifted completely out of the sand even if dead. If 'quicksand' is artificially produced by forcing sea water up through the sand, the clams come immediately to the surface and cannot re-enter the sand.

While on Heron Island, Queensland, Australia, I encountered the clam *Actactodea mitis* DESHAYES [= *A. striata* (GMELIN)] (ident. Tom Iredale). It was burrowing with its hinge line up and parallel to the shore in the wave zone of the coral sand beaches. The sand had a specific gravity of 2.86, while the clam's was 2.01, both measured by weighing them dry and determining the volume by water displacement. The clams were collected above the water line, averaged 21.6 mm in greatest diameter, and were wiped dry with a cleansing tissue. Clams with the same size distribution (to the nearest mm) collected *below* the water line had a specific gravity of 2.07,

presumably due to the retained water rather than air space in their mantle cavity.

When covered with one-half inch of sand or less at intervals of about 20 minutes, 50 of 150 clams elevated nine inches in six hours; when  $1\frac{1}{4}$  to  $1\frac{1}{2}$  inches of sand was added at hourly intervals, of 50 clams only 1 clam elevated three inches in 12 hours, two raised themselves two inches, and the rest stayed in place. Both sets were allowed to rebury after the counting to check for weak or dead clams. There were two and one individuals, respectively, who did not respond by reburying themselves.

The clam has a very short siphon. It lives just beneath the surface of the sand, with the siphon extending into the water. It possesses an obvious ability to elevate itself in the sand. It is to be noted that the difference between the specific gravity of *Actactodea mitis* and the coral sand is considerably less than that between ARMSTRONG's species which could not elevate themselves, and their inorganic sand. Perhaps clams in coral sands cannot depend on buoyancy to elevate them to the extent that clams can in inorganic sands, and thus tend to have mechanisms which enable them to actively elevate themselves in the sand.

The clams were placed between two glass plates, with native sand, allowed to burrow below the surface, and then additional sand was added to cause them to elevate in a manner as natural as possible. It could be seen that the shells contracted together and the foot pulled up, causing a 'rain' of sand down around the clam. The foot would be re-extended with a wiggling motion during the quiescent stage, and again the shells and foot would be contracted. No water currents were seen below the clam, but it is certain that the foot did not seem to *push* on the sand to elevate the clam. I think that the foot compacts the bottom sand to allow the grains to settle without binding up in the shell area.

ANSELL (1962) has reported the discussions in the literature regarding the mechanism whereby clams stop burrowing downward when they are 'deep enough'. Of course, one must be careful not to generalize that the behavior of even one species can be explained by a single mechanism, and certainly the behavior of a whole class cannot be explained with one parameter. FRAENKEL (1927) implies that in the solenids the correct depth is determined by fatigue, while ANSELL implies that in the venerids it is siphon extension. I can appreciate the work it would require for a long-siphoned clam to burrow to nearly the length of its siphon, so fatigue should be considered, but I believe that if these clams were dug up immediately one would find them capable of reburying themselves several more times, therefore fatigue cannot be the exclusive factor, and certainly siphon extensibility is a factor.

I exposed *Actactodea mitis* to repetitive burrowing by shaking the bucket, which caused them to be buoyed out of the sand and tipped over onto their sides, about every three minutes. Since I was after data on how many times the clams would rebury, I discarded clams that could not bury themselves in three minutes. They could dig into the sand up to the siphonal margins in 30 seconds, once they got started. I removed the stragglers (one or two clams at a time, except for one occasion with four individuals) to keep all digging clams at the same number of complete cycles. The diameter of the laggards was taken as they were removed, but no size trend was noted. The following table indicates the endurance of the 40 clams starting the test:

Number of reburials	Lapsed time, minutes	Number of clams remaining
5	22	36
10	34	31
15	45	24
20	56	19
25	68	8
30	90	5

## SUMMARY

*Actactodea mitis* was found to be able to elevate itself in coral sand at a rate of at least nine inches in six hours. A differential in specific gravity between clam and sand, together with a sifting of smaller sand grains beneath a larger clam could aid in this movement when the sand is moved by the clam's valves and foot, or by external water action. Selected individuals could rebury themselves 30 times in  $1\frac{1}{2}$  hours.

## ACKNOWLEDGMENTS

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New Distributional Records  
of some Northeastern Pacific Opisthobranchiata  
(Mollusca : Gastropoda)  
with Descriptions of Two New Species

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(12 Text figures)

## INTRODUCTION

RECENT COLLECTIONS of opisthobranchs from southern California and the northern shores of the Gulf of California have increased our knowledge of the distributional patterns of certain of these gastropods and provided data for the descriptions of two new species of nudibranchs. Many of these new records add to the list of species indigenous to both the temperate Californian and the northernmost regions of the subtropical Panamic faunistic provinces.

Excluding externally-shelled cephalaspideans and pelagic gymnosomes and thecosomes, only a few opisthobranchs have been reported to inhabit both regions. OLDROYD (1927, p. 52) stated that the notaspidean *Pleurobranchus digueti* ROCHEBRUNE, 1895, ranged from the Gulf of California (El Mogote, Bahía de la Paz) to San Pedro. No intermediate localities have been reported nor has the San Pedro record subsequently been verified. The common California sea hare, *Aplysia californica* COOPER, 1863, was tentatively identified from the Gulf of California (El Mogote, Bahía de la Paz, and Puerto Refugio, Isla Angel de la Guarda) by STEINBECK & RICKETTS (1941, p. 541). This species was later recorded by WINKLER (1958, pp. 106 - 107) from several Gulf localities.

Only 11 species of nudibranchs have been reported as common to both provinces. STEINBECK & RICKETTS (1941, p. 544) collected a specimen of *Melibe leonina* (GOULD, 1853) at Puerto Refugio, and LANCE (1961, p. 67) later found it at Bahía de la Paz. The burrowing arminacean *Armina californica* (COOPER, 1862) is known to occur along the coast of Panama, in the Gulf of California, and

from Ensenada to Vancouver Island. In a distributional list of southern California opisthobranchs, LANCE (1961, pp. 64 - 69) added *Diaulula sandiegensis* (COOPER, 1862); *Laila cockerelli* MACFARLAND, 1905; and *Capellinia rustya* MARCUS, 1961, to those species known from both provinces. FARMER & COLLIER (1963, pp. 62 - 63) extended southward the ranges of *Glossodoris californiensis* (BERGH, 1879); *Rostanga pulchra* MACFARLAND, 1905; *Dendrodoris albopunctata* (COOPER, 1863); *Dirona picta* MACFARLAND in COCKERELL & ELIOT, 1905; *Coryphella trilineata* O'DONOGHUE, 1921 (= *C. pinnata* MARCUS, 1961); and *Hermisenda crassicornis* (ESCHSCHOLTZ, 1831) to include localities within the Gulf of California.

In view of the impending publication in this journal of a comprehensive guide to the opisthobranchs occurring along the west coast of the continental United States, the present contribution is intended to summarize the current state of our knowledge concerning southern distributions. Two new species are here described in order to make possible their inclusion in the forthcoming keys.

I am deeply grateful to Faye Howard, Fay Wolfson, and Gale Sphon, whose collections from the Gulf of California have greatly facilitated this work. Also I am indebted to James Morin, Lawrence Andrews, Wesley Farmer, and James McLean for providing me with additional data on California species. To Joan Steinberg I wish to express my sincere appreciation for her many valuable suggestions and criticisms during the preparation of this paper. The constant encouragement and profound patience of our editor, Rudolf Stohler, is gratefully acknowledged.

Latitudes and longitudes for the geographical points mentioned are given in the following table.

**Alaska**

Sitka	57° 03' N	135° 20' W
Dall Island	55° 00' N	133° 00' W

**British Columbia**

Rosepit, Graham Island	54° 08' N	131° 40' W
Nanaimo, Vancouver Isld.	49° 10' N	123° 56' W

**Washington**

San Juan Island	48° 30' N	123° 00' W
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**California**

Tomales Bay	38° 14' N	122° 59' W
San Francisco Bay	37° 47' N	122° 27' W
Monterey Bay	36° 39' N	121° 53' W
Pacific Grove	36° 38' N	121° 55' W
Santa Barbara	34° 25' N	119° 41' W
Santa Cruz Island	34° 01' N	119° 41' W
San Pedro	33° 44' N	118° 16' W
Newport Bay	33° 36' N	117° 54' W
Laguna Beach	33° 32' N	117° 44' W
La Jolla	32° 52' N	117° 15' W
Mission Bay	32° 46' N	117° 14' W
San Diego	32° 42' N	117° 11' W
Point Loma	32° 40' N	117° 14' W

**Mexico**

Islas los Coronados	32° 24' N	117° 14' W
Ensenada	31° 51' N	116° 38' W
San Felipe	31° 03' N	114° 50' W
Puertecitos	30° 25' N	114° 39' W
Bahía San Luis Gonzaga	29° 48' N	114° 25' W
Isla Angel de la Guarda (Puerto Refugio)	29° 33' N	113° 35' W
Bahía de los Angeles	28° 55' N	113° 32' W
Laguna Manuela	28° 11' N	114° 04' W
Guaymas (San Carlos)	27° 55' N	110° 54' W
Isla Natividad	27° 53' N	115° 10' W
Punta Eugenia	27° 51' N	115° 05' W
Bahía Tortuga	27° 41' N	114° 53' W
Punta Abrejos	26° 43' N	113° 34' W
Bahía de la Concepcion	26° 43' N	111° 54' W
Bahía de la Magdalena	24° 38' N	112° 09' W
Bahía de la Paz	24° 10' N	110° 17' W

**Chile**

Isla de Chiloé	41° 52' S	73° 50' W
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**SYSTEMATIC LIST OF SPECIES TREATED****CEPHALASPIDEA****Philinacea****AGLAJIDAE**

1. *Navanax inermis* (COOPER, 1862)

**NOTASPIDEA****Pleurobranchacea****PLEUROBRANCHIDAE**

2. *Berthella californica* (DALL, 1900)

**SACCOGLOSSA****Elysiacea****ELYSIIDAE**

3. *Elysia hedgpethi* MARCUS, 1961

**STILIGERIDAE**

4. *Stiliger fuscovittata* LANCE, 1962

**NUDIBRANCHIA****Doridacea****EUDORIDACEA****Cryptobranchia****DORIDIDAE**

5. *Glossodoris californiensis* (BERGH, 1879)
6. *Rostanga pulchra* MACFARLAND, 1905
7. *Thordisa bimaculata* LANCE, 1966, spec. nov.
8. *Conualaevia alba* COLLIER & FARMER, 1964

**Phanerobranchia****NONSUCTORIA****NOTODORIDIDAE**

9. *Aegires albopunctatus* MACFARLAND, 1905

**POLYGERIDAE**

10. *Polycera hedgpethi* MARCUS, 1964

**SUCTORIA****GONIODORIDIDAE**

11. *Okenia angelensis* LANCE, 1966, spec. nov.
12. *Trapania velox* (COCKERELL, 1901)
13. *Ancula lentiginosa* FARMER & SLOAN, 1964

**DENDRONOTACEA****TETHYIDAE**

14. *Melibe leonina* (GOULD, 1853)



## Arminacea

## PACHYGNATHA

## DIRONIDAE

15. *Dirona albolineata* MACFARLAND, 1912

## Aeolidacea

## ACLEIOPROCTA

## CUTHONIDAE

16. *Cuthona alpha* BABA & HAMATANI, 1963

## CLEIOPROCTA

## FACELINIDAE

17. *Hermisenda crassicornis* (ESCHSCHOLTZ, 1831)

## AEOLIDIIDAE

18. *Spurilla chromosoma* COCKERELL & ELIOT, 1905

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1. *Navanax inermis* (COOPER, 1862)

This distinctive species has been reported to range from Monterey Bay to Ensenada (MACGINITIE & MACGINITIE, 1949, p. 372). Although in southern California it sometimes occurs along the open coast in rocky intertidal regions and certain subtidal areas to a depth of 33 m, it is primarily an inhabitant of bays and estuaries and in this environment attains maximum size. PAINE (1963) has conducted a unique study demonstrating that *Navanax inermis* is primarily a selective predator of other opisthobranchs and locates its prey by contact chemoreception of mucus sand trails.

Six specimens collected at Laguna Manuela on the west coast of the Baja California peninsula on 8 II 1954 extend the range southward. Field trips to Bahía de los Angeles on 14 IV and 13 V 1964 resulted in the collection of two and three slugs respectively, thus establishing it as a component of the Panamic fauna.

2. *Berthella californica* (DALL, 1900)

1900. *Pleurobranchus californicus* DALL, p. 92  
 1927. *P. californicus*, OLDROYD, p. 52  
 1948. *P. californicus*, SMITH & GORDON, p. 180  
 1957. *P. californicus*, STEINBERG, p. 268  
 1961. *P. californicus*, LANCE, p. 65  
 1963. *P. californicus*, PAINE, p. 5  
 1963 b. *P. californicus*, STEINBERG, p. 69

Occurrence: Monterey (off breakwater), 7 III 1965, one slug obtained by diver at 13 m (Powell, communicated record); Pacific Grove at low tide under rocks, rare

(SMITH & GORDON); San Pedro (type locality), two slugs (DALL); La Jolla, 6 V 1960, two slugs obtained by divers at 33 m (LANCE); Mission Bay (on jetty near entrance), 28 II 1965, three slugs under rocks at low tide (LANCE); Point Loma, 3 IX 1955, one slug under rock at low tide (LANCE).

According to modern systematic concepts of the not-aspidéan family Pleurobranchidae, *Pleurobranchus californicus* DALL, 1900, must be transferred to *Berthella* BLAINVILLE, 1825.

In his original description DALL clearly states. "The gill short, its stem finely granular, not tuberculate . . . jaws and teeth as described by Pilsbry for the Gulf of California species collected by Fischer (Man. Conch. xvi, pp. 201-202) . . . The shell itself is white and thin . . . the whole extends more than half the length of the body . . ." PILSBRY reports that Fischer's specimen had "Teeth of the radula simply hooked, with no denticulation."

Contemporary authors (ODHNER, 1939, p. 16; BURN, 1962, pp. 129-131; MACNAE, 1962, p. 168) treating the shelled pleurobranchs appear to agree on a division of the genera based on the configuration of the gill rhachis. In one group the rhachis bears a linear series of prominent tubercles; in the other it is smooth or transversely grooved. *Pleurobranchus* CUVIER, 1805, along with two or three other genera belongs to the former group. The latter group comprises three genera: (1) *Berthella* BLAINVILLE, 1825, with a smooth gill rhachis, hook-shaped radular teeth, and a shell at least half the body length; (2) *Berthellina* GARDINER, 1936, with a smooth gill rhachis, serrate lamelliform teeth, and a shell less than  $\frac{1}{2}$  the body length; and (3) *Berthellinops* BURN, 1962, with a transversely grooved gill rhachis, hook-shaped radular teeth, and a shell  $\frac{1}{2}$  the body length.

In view of these considerations it is evident that DALL's species with a smooth gill rhachis, hook-shaped radular teeth, and a shell longer than  $\frac{1}{2}$  the body length should correctly be known as *Berthella californica*.

*Pleurobranchus digueti* ROCHEBRUNE, 1895, the only other described pleurobranch reported from the north-eastern Pacific is an entirely different species. It is several times larger, bright orange, and common in the Gulf of California. The only record of its occurrence outside the Panamic province is that of OLDROYD (1927, p. 52) who indicated that its range included San Pedro.

3. *Elysia hedgpethi* MARCUS, 1961

Although a large number of temperate and subtropical species has been assigned to *Elysia* the present form is the sole representative known from the northeastern Pacific.

The original description (MARCUS, 1961, pp. 13-14) was based on three specimens obtained from mud flats at Tomales Bay. LANCE (1961, p. 65) found the species to be a common spring and summer resident in the intertidal regions at La Jolla. STEINBERG (1963b, p. 69) extended the range northward to San Juan Island where it was observed on the green alga *Codium* sp.

The range is here extended to include the Gulf of California (Bahía de los Angeles) where eight slugs were found on *Codium* sp. in the rocky low intertidal region on 14 IV 1964. An additional eight specimens were collected in the same area on 13 V 1964.

#### 4. *Stiliger fuscovittata* LANCE, 1962

This species, originally described from a large number of individuals collected on boat landings in Mission Bay, has recently been reported from a similar habitat at San Juan Island (STEINBERG, 1963b, p. 69). It has been observed only in immediate association with *Polysiphonia* sp. and is presumed to feed upon this red filamentous alga.

Several individuals have recently been collected on clumps of a similar or identical species of *Polysiphonia* in the exposed intertidal region at Bahía de los Angeles on 13 IV 1964. A visit to the same area on 12 V 1964 resulted in the collection of additional specimens and their nido-somes.

#### 5. *Glossodoris californiensis* (BERGH, 1879)

The geographic range of this species has been reported to extend from Monterey to Islas los Coronados off the northern Pacific coast of Baja California (LANCE, 1961, p. 66; STEINBERG, 1963, p. 69). This southern range limit was, however, in error as BERGH (1894) had already reported the species from the region of Bahía Magdalena in the southern part of the peninsula of Baja California.

FARMER & COLLIER (1963, p. 62) subsequently extended the range to include the Gulf of California as a result of obtaining specimens at Isla Angel de la Guarda. Considering the following additional localities from which individuals have been collected, it appears that the species is a fairly common intertidal inhabitant of at least the northern regions of the Gulf: 5 miles north of Guaymas (San Carlos), 6 I 1966, 1 slug; 12 miles south of Puertecitos, 8 VI 1963, 1 slug; 4 miles south of Puertecitos, 20 III 1965, 2 slugs; Puertecitos, 1 IV 1962, 1 slug; 15 miles north of Puertecitos, 8 VI 1963, 1 slug; a few miles south of San Felipe, V 1960, 1 slug; immediately south of San Felipe, 24 III 1963, 1 slug.

#### 6. *Rostanga pulchra* MACFARLAND, 1905

This species appears to occur primarily in the intertidal regions and has been reported to range from Vancouver

Island (O'DONOGHUE, 1922, p. 154) to Point Loma (MARCUS, 1961, p. 15). ELIOT (1907, p. 339) and BABA (1935) synonymized *Rostanga pulchra* MACFARLAND, 1905, with the Indo-Pacific *R. arbutus* (ANGAS, 1864). MARCUS (1958, p. 25; 1959, pp. 36-37; 1961, p. 16) has provided ample evidence for separating the two species. Accordingly, Japan (LANCE, 1961, p. 66; STEINBERG, 1963, p. 70; FARMER & COLLIER, 1963, p. 62) must be excluded from the range.

MARCUS (1959, pp. 35-37) allocated three specimens collected along the coast of Isla Chiloé (Chile) to *Rostanga pulchra*. Whether this remarkably isolated record represents a disjunct population, or simply reflects our almost total lack of knowledge of Panamic and Peruvian opisthobranchs, can only be determined after considerably more collecting has been carried out along the intervening west coasts of Mexico, and Central and South America.

The first record of the occurrence of *Rostanga pulchra* in the Gulf of California was reported by FARMER & COLLIER (1963, p. 62) who obtained several individuals from Isla Angel de la Guarda. Additional specimens from adjacent localities have recently been found at Bahía de los Angeles (13 IV 1964, 2 slugs), Bahía San Luis Gonzaga (5 II 1966, 2 slugs), and 4 miles south of Puertecitos (19 III 1965, 1 slug).

#### 7. *Thordisa bimaculata* LANCE, spec. nov.

1963. ?*Thordisa*, PAINE, p. 4

1963. *Aldisa sanguinea*, FARMER & COLLIER, p. 62

**Type locality:** Windnsea Reef, La Jolla, California (middle intertidal zone).

**Type:** The holotype is an entire animal deposited at the California Academy of Sciences, Department of Invertebrate Zoology, where it is registered as CAS No. 100. Four paratypes, CAS Nos. 262, 263, 264, and 265 have been deposited at the same institution. All type material was collected May 31, 1965.

**Name:** The specific name *bimaculata* was chosen to call attention to the two areas of contrasting dark pigment found on the notum of most individuals.

**Occurrence:** This species is locally common intertidally along rocky shores of La Jolla and San Diego during the summer. Two specimens were collected at the type locality on 9 XI 1965. On 12 XII 1960, two individuals were taken at 33 m in Carmel submarine canyon (off Carmel, California) by J. McLean (personal communication.) This is the only verifiable record north of La Jolla. FARMER & COLLIER (1963, p. 62) reported this species from Isla Natividad under the misnomer *Aldisa sanguinea* (personal communication).

**Description:** The average of a large series of adults measured 28mm long 12mm broad, and 6.5mm high. The body is typically doridiform, rounded in front, with nearly parallel sides, and terminating posteriorly in a bluntly pointed tail which extends beyond the notum (Figure 1). The branchiae are completely retractile with-

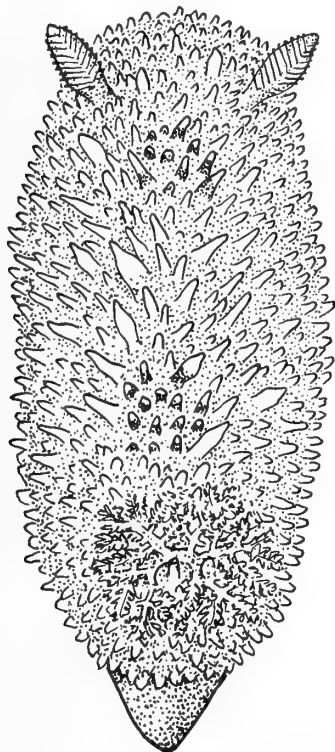


Figure 1

*Thordisa bimaculata* LANCE  
Living animal, dorsal aspect.

in branchial pits. The notum is convex, highest along the midline, and slopes gradually downward to its periphery. The entire dorsal surface of the notum is thickly set with inflated villous papillae longest medianly and gradually decreasing in size outward. In life the larger papillae are constricted near the base, become inflated about halfway up, and terminate in a gradually tapering point (Figure 2). Protruding spicules (Figure 2, b) occur in the constricted areas.

The anterior margin of the foot is rounded and bilabiate with both lips entire, not cleft in life (Figure 3). In preserved material the upper lip often appears slightly invaginated. The foot sides are nearly parallel and covered all around except posteriorly where they taper into a

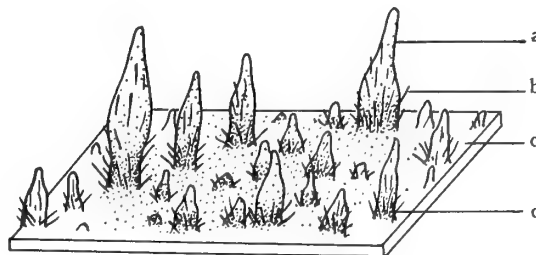


Figure 2

*Thordisa bimaculata* LANCE  
Notal detail in spotted area.

- |                       |                                  |
|-----------------------|----------------------------------|
| a. papilla            | c. notum                         |
| b. protruding spicule | d. concentration of dark pigment |

bluntly pointed tail which extends for a moderate distance beyond the notal margin. The foot is about  $\frac{2}{3}$  the width of the body. In antero-ventral aspect the head region appears only as two broad, fleshy lateral lobes (Figure 3, a) flanking the mouth (Figure 3, b). Two

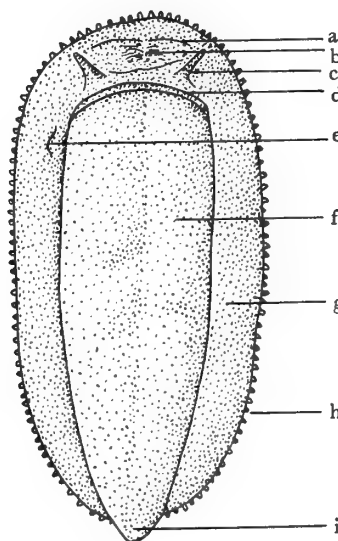


Figure 3

*Thordisa bimaculata* LANCE  
Living animal, ventral aspect.

- |                                   |                          |
|-----------------------------------|--------------------------|
| a. oral lobe                      | e. external genital pore |
| b. mouth                          | f. foot                  |
| c. oral tentacle                  | g. hyponotum             |
| d. bilabiate anterior foot margin | h. notal papilla         |
|                                   | i. tail                  |

slender digitiform tentacles (Figure 3, c) arise on either side of the mouth somewhat posterior to the lateral lobes. Unlike the ventral cephalic topography of many crypto-branch dorids, the tentacles of *Thordisa bimaculata* are not prolongations of the lateral margins of the oral lobes, but arise independently.

The general ground color varies from bright orange to dull yellowish. A contrasting spot of brown pigment is present along the median line of the notum just behind the rhinophores. A similar spot occurs in front of the branchiae. The pigment in these areas is concentrated primarily on the bases of the papillae rather than on the notal surface. In some individuals the pigmentation is very pale or absent. The rhinophores are darker than the body due to a concentration of brown pigment along the margins of their lamellae. In life, the branchiae are usually lighter than the body in brightly colored individuals, or the same color in paler animals; they are never a contrasting white. In a few specimens the branchial stems may be faintly tinted with purple. The smaller notal papillae are usually tipped with a minute white ring observable only under the dissecting microscope.

The stout rhinophores retract into upstanding papillated sheaths. The stalk is short; the clavus deeply perfoliate with 14 - 16 nearly horizontal lamellae. There is no conspicuous axial septum connecting either the anterior or posterior faces of the lamellae. The clavus is furrowed along its anterior axis and terminates distally in a short cylinder with a flat apex.

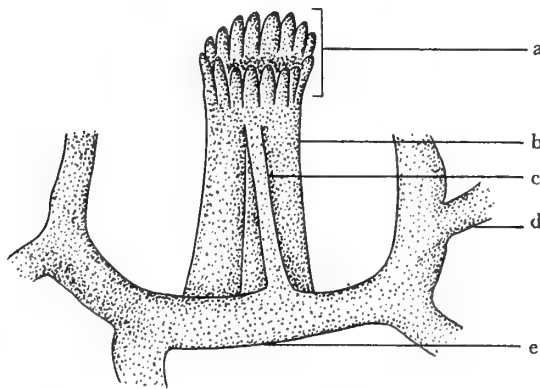


Figure 4

*Thordisa bimaculata* LANCE

Anal papilla topography, anterior aspect.

- a. convoluted apex
- b. anal papilla
- c. connecting septum
- d. primary branchial stem
- e. branchial base

The six bi- and tripinnate branchiae are upstanding, not spreading beyond the notal borders, and carried at a 45° angle to the horizontal. They are joined at their bases by a prominent horseshoe-shaped septum which is carried above the upstanding tuberculate margins of the branchial pit. The tall anal papilla is located within the circlet of branchiae and bears a number of creases distally (Figure 4). A distinct septum (Figure 4, c) connects its anterior face to the branchial base (Figure 4, e).

The labial cuticle is strong, nearly transparent, and without any trace of armature (Figure 5). Its surface is tessellated. A typical individual 28 mm in length had a radula formula, 32 x 8-34-0-34-8 at the level of the 17th row. Another specimen of the same length had the formu-

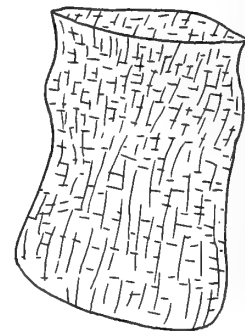


Figure 5

*Thordisa bimaculata* LANCE  
Labial cuticle, lateral aspect.

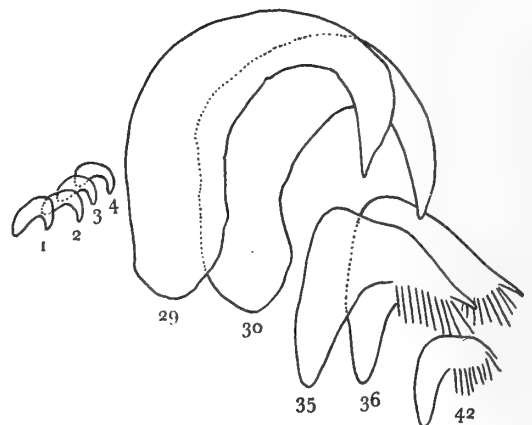


Figure 6

*Thordisa bimaculata* LANCE

Representative teeth from 16th row of radula.

la 31 x 6.29-0.29-6 at the same level. Several other individuals examined showed only moderate variation in both number of rows and number of teeth per row at any given level. The innermost laterals are small hamate hooks and increase in size outwards. The outermost 6-10 laterals (marginals) abruptly become bristled, bear a prominent cusp similar to that figured for *Thordisa diuda* (MARCUS, 1955, pl. 15, fig. 139), and decrease in size outwards (Figure 6).

The spicules are straight or slightly curved smooth rods (Figure 7). Those occurring around the under surface of the notum form a reticulum similar to that found on the hyponotum of *Dendrodoris albopunctata*.

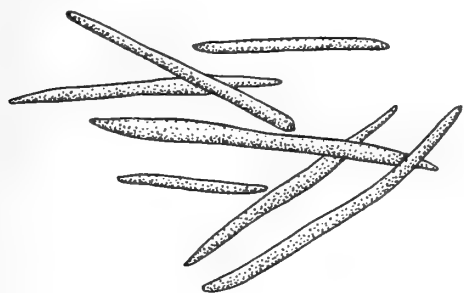


Figure 7

*Thordisa bimaculata* LANCE  
Spicules from notal margin.

The genital apertures are located on the right side at the junction of the notum with the body side and somewhat behind the level of the rhinophores (Figure 3, e). The penis is armed with 7-10 large spines longitudinally oriented (Figure 8, a). Each spine consists of a single large hook arising towards the end of a subrectangular thickened base (Figure 8, b).

The pale to bright yellow nidosomes are flat sinistrally-coiled ribbons of three to five whorls and are attached to the substrate along one edge. The free margin is slightly convoluted. The two individuals collected 9 XI 1965 from La Jolla produced nidosomes with viable embryos in the aquarium as readily as those collected during the summer months.

Specimens with varying amounts of sand grains attached between the notal papillae are often observed in the field. In some cases the animals are heavily encrusted and barely discernible against the substrate. BURN (1957, p. 12) has also noted this phenomenon for the related south Australian species *Thordisa sabulosa*, and concludes that the dorsal papillae extrude an adhesive fluid.

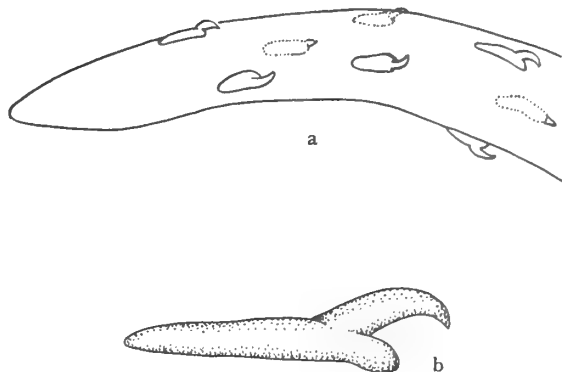


Figure 8

*Thordisa bimaculata* LANCE  
Male genital armature

a. penis with hooks

b. detail of hooks

*Thordisa bimaculata* is easily distinguished from all other cryptobranch dorids so far recorded from the north-eastern Pacific by the shape and relative size of the notal papillae. Internally the species may be determined by the characteristic arrangement and structure of the radular teeth and penial armature.

#### 8. *Conualaevia alba* COLLIER & FARMER, 1964

This genus and the new subfamily Conualaevinae were proposed by the above authors to receive two new species of cryptobranch dorids with the novel distinction of possessing smooth rhinophores. One of the species, *Conualaevis marcus*, is known only from the northwestern regions of the Gulf of California. The other, *C. alba*, was reported from intertidal areas at Newport Bay and Point Loma.

Three individuals of the latter species were collected under stones at Bahía Tortuga on 11 IV 1954, extending the range southward along the Pacific coast.

#### 9. *Aegires albopunctatus* MACFARLAND, 1905

This common phanerobranch dorid occurs subtidally, intertidally, and on bay boat landings from Vancouver Island (O'DONOGHUE, 1927) to Ensenada (FARMER & COLLIER, 1963, p. 62). It is one of the most abundant species at least during the summer months in the intertidal regions at Moss Beach, La Jolla, and San Diego.

A specimen noted only as *Aegires* sp. was collected by STEINBECK & RICKETTS (1941, p. 543) in the Gulf of California (Puerto Refugio). Two individuals found

under stones in the low intertidal area at Bahía de los Angeles (13 IV 1964, 1 slug; 13 V 1964, 1 slug) establish this species as an additional component of the Panamic fauna.

10. *Polycera hedgpethi* MARCUS, 1964

The only records of *Polycera hedgpethi* for the Pacific coast of the United States are those from central and southern California. MARCUS (1964, pp. 128 - 131) described the original material from two specimens obtained on *Bugula* sp. in Tomales Bay. Numerous individuals have subsequently been found in San Francisco Bay during the late spring and summer months - also on *Bugula*. One slug was collected in Mission Bay on 18 VII 1964, and another on 10 X 1965, on the same bryozoan species.

At Bahía de los Angeles and its immediate environs this is one of the most abundant nudibranchs, at least during the spring and early summer. At least 50 slugs were observed feeding among colonies of *Bugula* sp. growing on intertidal *Sargassum* sp. on 7 V 1961. Return visits to the area on 14 IV and 13 V 1965 resulted in the collection of numerous specimens. Irregular white egg ribbons, presumably of this species, were abundantly draped among the bryozoan colonies.

11. *Okenia angelensis* LANCE, spec. nov.

**Type locality:** Bahía de los Angeles, Estado de Baja California, Mexico (lowest intertidal zone).

**Type:** The holotype is an entire animal deposited at the California Academy of Sciences, Department of Invertebrate Zoology, where it is registered as CAS No. 101. Four paratypes, CAS Nos. 280, 281, 282, and 283, are deposited at the same institution. The specimens were collected 7 May 1961.

**Name:** The specific name *angelensis* was chosen to indicate the geographic region where the species was first observed.

**Occurrence:** This species is not uncommon locally and seasonally in its respective habitats. In the Gulf of California it is known only from *Sargassum* sp. beds at Bahía de los Angeles. Six specimens were collected among colonies of campanularian hydroids on 7 V 1961. In California it is an inhabitant of bay boat landings: San Francisco Bay, 3 IX 1964, 1 slug (Andrews, personal communication); Monterey Bay, IX, 1963, 9 slugs (Andrews, personal communication); Santa Barbara Yacht Harbor (a specimen identified from a color transparency); Mission Bay, 31 specimens collected throughout the year 1965.

**Description:** The largest adult specimen examined was 10 mm long and 2.5 mm broad when actively crawling.

Most individuals were 6 to 8 mm long and 1.5 to 2.0 mm broad.

The body is firm in texture and elongate with high vertical sides and a prominent pallial ridge extending beyond the foot margin (Figure 9). The ridges unite

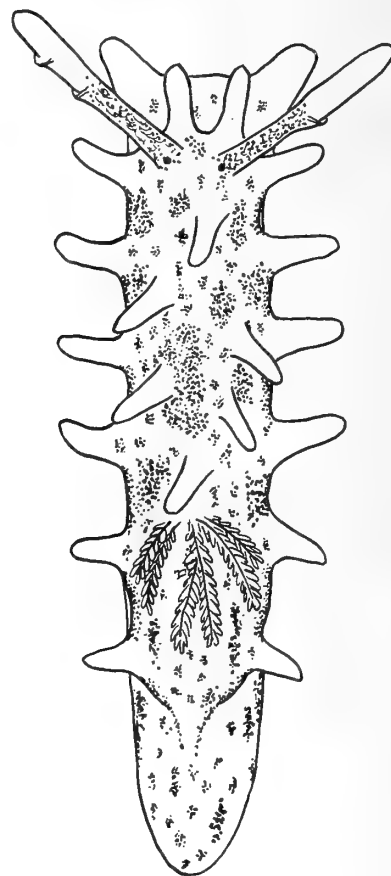


Figure 9

*Okenia angelensis* LANCE  
Living animal, dorsal aspect.

behind the branchiae to form a median crest which rapidly terminates on the flat, rounded tail. Anteriorly the ridges continue in front of and below the rhinophores. On each side the pallial ridge gives rise to 6 - 9 robust digitiform papillae which project outward in a more or less horizontal plane. Typically, one pair of papillae occurs anterior to the rhinophores, four or five behind the rhinophoral level, and two pairs behind the branchiae. Five or six similar papillae more or less equidistant from each other occur on the notum between the rhinophores and branchiae - primarily on the pericardial hump.



In ventral aspect (Figure 10) the antero-lateral corners of the head are developed into a pair of fleshy, pointed extensions (Figure 10, a). The mouth (Figure 10, b) is a simple longitudinal slit dividing the rounded oral lobes (Figure 10, c). The foot is slightly narrower than the body proper and coalesces along its antero-lateral corners with the body sides to form a simple anterior margin (Figure 10, d). The sides of the foot are nearly parallel and pass backward into a blunt tail.

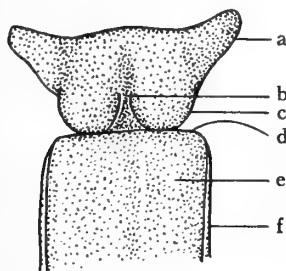


Figure 10

*Okenia angelensis* LANCE

Living animal, antero-ventral aspect.

- a. antero-lateral head extension    e. foot  
b. mouth    d. simply labiate anterior foot margin  
c. oral lobe    f. side of body

The color pattern is drab and along with the animal's diminutive size renders it very inconspicuous. The ground color is translucent white with the pale yellowish internal organs faintly showing through in the mid-dorsal region. The entire body except the foot sole is sparsely flecked with minute yellowish and white granules. Varying concentrations of reddish-brown dots, often gathered into irregular patches and streaks, occur over this same area but not on the papillae or other appendages except for the proximal half of each rhinophore and occasionally on the principal stems of the branchiae. In some slugs concentrations of subepidermal bluish-green pigment are found along the dorsal and ventral margins of the pallial ridge and on the body sides at the junctions with the foot.

The nonretractile rhinophores are long, tapering rods set apart from each other. Their apices are rounded, not flattened. Most specimens bear one to three incomplete lamellae along the posterior surface of each rhinophore, although these sensory organs are completely smooth in some individuals. No slugs bearing numerous lamellae have been observed.

There are five to seven nonretractile gills separated at their bases. The antero-median member is the largest and is often deeply bifurcate near the insertion of the

primary stem. A similar condition is known to occur in *Okenia evelinae* (MARCUS, 1957, p. 439) and *O. japonica* (BABA, 1949, p. 138). The anterior central gill is usually bipinnate, rarely tripinnate. The following paired members decrease in size and structural complexity with the hindmost pair simply pinnate. The anal opening is on a low rounded papilla and located immediately posterior to the median gill.

The black eye spots are fairly conspicuous and lie buried under the rhinophore bases. The genital aperture occurs high up on the right side under the pallial ridge and between the third and fourth pallial papillae. The penis is unarmed.

The radular teeth are typical for the genus (Figure 11). In a typical specimen 7 mm in length the formula was  $21 \times 1.10.1.1$ . The first lateral tooth is hamate with a broad base and on its inner side bears a linear series of 25 - 30 denticles which progressively increase in size from the base of the hook toward its tip (Figure 11, a). The flattened marginal teeth are oval to subquadrangular in

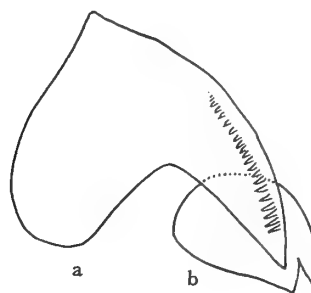


Figure 11

*Okenia angelensis* LANCE

Representative half row of teeth from center of radula.

- a. inner lateral    b. outer lateral

outline and bear a single prominent notch, the points of which may be somewhat elongated (Figure 11, b). No jaws or labial cuticle were observed.

Nodulose spicules in the form of elongate irregular rods occur throughout the integument but are concentrated along the pallial ridge and sides of the body (Figure 12).

**Remarks:** The subgenera *Okenia* with median papillae on the notum, and *Idaliella* without, comprise the phanerobranch genus *Okenia* MENKE, 1830 (MARCUS, 1957, pp. 436, 440). PRUVOT-FOL's (1954, p. 308) character "... rhinophores longues avec nombreuses lamelles oblique peu prééminentes" must be emended to include the present species with few incomplete lamellae or none.

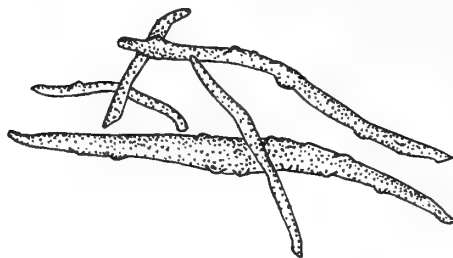


Figure 12

*Okenia angelensis* LANCE  
Spicules from pallial ridge.

MARCUS (1957, pp. 436, 438) listed 15 species of *Okenia* generally recognized as valid. BABA (1960, pp. 80, 81) and HAMATANI (1961, pp. 363 - 365) have since described three new species from Japan. *Okenia angelensis* may be distinguished from all these by its nearly absent rhinophoral perfoliation and color pattern.

Two other members of the genus have been recorded from the northeastern Pacific. O'DONOGHUE (1921, p. 177) described *Okenia vancouverensis* from three specimens "... probably dredged in fairly shallow water of from 10-15 fathoms." obtained off Rosepit, Graham Island (Queen Charlotte Islands). This British Columbia species differs from *O. angelensis* by its deeply perfoliate rhinophores, more numerous notal papillae, much larger size, 14 simply pinnate branchiae, and shape of the radular teeth. It has not been reported since the original description. The other northeastern Pacific species, *O. plana* BABA, 1960, was originally described from specimens obtained along the coast of Japan. During that same year STEINBERG (1960, p. 49) reported *Okenia* sp. from several localities within San Francisco Bay, and later (1963 a, p. 65; 1963 b, p. 71) identified her specimens as belonging to the Japanese *O. plana*. The Japanese species differs from *O. angelensis* by its flattened body with a semicircular head veil, lack of a pallial ridge, single median papilla on the notum, perfoliate rhinophores, greater number of branchiae, highly expanded foot, denticulation of the radular teeth, and color pattern.

#### 12. *Trapania velox* (COCKERELL, 1901)

The brief original description of this species was provided by COCKERELL (1901, p. 87) from a living specimen collected among intertidal rocks at La Jolla. As a result of examining another living individual from the same

locality, MACFARLAND (1929) furnished a more detailed account of the morphology and internal anatomy.

In a recent list of southern California opisthobranchs (LANCE, 1961, p. 67) I reported this species to range from San Diego Bay to San Francisco Bay. However, the latter locality is very doubtful as STEINBERG (1963 b, p. 71) has already pointed out, and we have been unable to verify the original report. Four specimens have recently been identified from the Santa Barbara Yacht Harbor thus confining the presently known range to southern California.

#### 13. *Ancula lentiginosa* FARMER & SLOAN, 1964

This species is known mainly from the original lot of twelve slugs collected in sea water pipes at the Scripps Institution of Oceanography, La Jolla, VI 1963. Two ovigerous specimens were subsequently found (IX 1965) crawling on seawater tables utilizing the same water source. The species has recently been collected at the Monterey Yacht Harbor (Steinberg, personal communication).

On 14 IV 1964 I collected a single adult individual in the rocky intertidal region at Bahía de los Angeles, thus tentatively establishing it as a component of the Panamic fauna.

#### 14. *Melibe leonina* (GOULD, 1853)

Many localities between Dall Island, Alaska (HEATH, 1917, p. 137) and Santa Barbara (COOPER, 1863, p. 60) have been reported for this species (see also O'DONOGHUE 1926, pp. 226-227). During cruises to the kelp canopies (*Macrocystis*) off Point Loma, La Jolla, and Santa Cruz Island, IV 1960 and V 1961, I observed hundreds of specimens actively crawling among the upper blades and stipes of the alga. Characteristic nidosomes were also abundant. Similar observations were made earlier on populations inhabiting kelp beds off Bahía Tortuga (13 IV 1954) and Punta Abreojos (8 IV 1954) on the Pacific side of the peninsula of Baja California.

STEINBECK & RICKETTS (1941, p. 544) were the first authors to report *Melibe leonina* from the Gulf of California. By the aid of a lamp hung over the side of the ship at night they netted a single specimen as "... it was seen swimming past the boat ..." at Puerto Refugio. Subsequently I extended the range to include Bahía de la Paz as a result of collecting a slug found on floating *Sargassum*. Further specimens from attached intertidal *Sargassum* have been found at Bahía de los Angeles (13 IV 1964, 2 slugs; 12 V 1964, 1 slug). A few nidosomes were observed on both occasions.

*Melibe leonina* does not occur along the open Pacific coast in intertidal regions except accidentally and to my knowledge has never been taken by dredging. It is not uncommon on floating kelp entangled around pilings and boat landings.

15. *Dirona albolineata* MACFARLAND in COCKERELL & ELIOT, 1905

MACFARLAND (1912) gave a detailed description of this spectacular species from material collected along the south shores of Monterey Bay and adjacent coast. It was later reported north to Vancouver Island and south to Laguna Beach (O'DONOGHUE, 1927 b, p. 103). Two large specimens were recently collected by divers off La Jolla at about 30 m (VII 1962). This record extends the range somewhat to the south.

16. *Cuthona alpha* BABA & HAMATANI, 1963

Occurrence: Mission Bay, 10 I 1965, 1 slug; 3 XII 1965, 1 slug; Newport Bay, 25 IV 1965, 2 slugs; Santa Barbara Yacht Harbor, 1964, 1 slug.

Of the four living specimens examined, the largest was 10 mm long and 2 mm broad. The fifth, from Santa Barbara, was identified from a color transparency. All were collected on boat landings in protected waters.

This brightly colored aeolid has been known previously only from the coasts of Japan. A brief description is offered here to facilitate identification by west coast investigators. For additional information and anatomical details see BABA & HAMATANI (1963, pp. 339 - 343).

The body is typically aeolidiform with the cerata given off in five or six overlapping but fairly distinct groups. The anterior two groups each contain three or four rows; those following, a single row each. The cerata are cylindrical, tapering to rounded tips, and without conspicuous cnidosacs. Those more median are the largest. The two most anterior groups originate posterior to the rhinophore insertions, not directly below them.

The rhinophores are simple tapering rods about  $\frac{1}{3}$  longer than the cephalic tentacles. There is no trace of perfoliations or annulations in living specimens. Preserved material sometimes presents a "wrinkled" appearance. The conspicuous black eye spots are near the surface of the integument and immediately postero-lateral to the rhinophore insertions. The genital orifice is located on the right side just below the insertion of the most anterior cerata. The anus is interhepatic, i. e. between the right and posterior livers.

The color pattern of this species is distinct and enables it to be readily distinguished from all aeolid nudibranchs described from the northeastern Pacific. The ground color

is translucent white with brown digestive diverticula which form the cores of the cerata and their subnotal connections. For most of its length the antero-dorsal surface of each ceras, except the smallest, is covered with a highly contrasting, intense opaque-white pigment which appears crustose under the dissecting microscope. The pigment is iridescent and reflects primary colors. It also occurs on the dorsal surface of the head as a triangular patch and continues forward between the rhinophores to bifurcate and terminate at the distal end of the cephalic tentacles. Two ill-defined lines of the same pigment run along the sides of the head from the antero-lateral corners of the triangular patch to the anterior insertions of the cerata. Flecks of the pigment occur sparsely on the notum between the cerata. A diffused, bright orange pigment is present on the median half of the dorsal surface of the cephalic tentacles overlaying the deeper white stripe. The distal third of each rhinophore is bright orange. According to the original description of specimens from Japan and my own observations of local material, the intensity of the orange pigment is subject to considerable variation.

Southern California specimens agree in every respect with the description of the Japanese type material and I have no hesitation in identifying the local specimens accordingly.

17. *Hermisenda crassicornis* (ESCHSCHOLTZ, 1831)

Although *Hermisenda crassicornis* inhabits the Pacific coast from Sitka (ESCHSCHOLTZ, 1831) to Punta Eugenia (LANCE, 1961, p. 68; STEINBERG, 1963 b, p. 72), its local distribution in the northern part of the range is unknown. From at least central California south to San Diego it is one of the most common nudibranchs and may be observed in almost any habitat throughout the year. Populations appear to reach their greatest density in the intertidal regions during the spring and summer months, but I have observed vast numbers of copulating slugs and their nidosomes on Mission Bay boat landings during November and December.

FARMER & COLLIER (1963, p. 63) reported a single specimen from the intertidal region at Isla Angel de la Guarda, thus extending the range into the Panamic province. Additional slugs from northern locations in the Gulf of California have been collected at Bahía de los Angeles (6 V 1961, 1 slug); four miles south of Puertecitos (20 III 1965, 1 slug); Guaymas (7 I 1966, 1 slug); and San Luis Gonzaga (5 II 1966, common). The last record is particularly noteworthy because it indicates that substantial populations, not merely stragglers, occur at least in the northern regions of the Gulf. During the same series of minus tides a number of field trips to the inter-

tidal regions of La Jolla and San Diego resulted in the collection of only two individuals of this species.

#### 18. *Spurilla chromosoma* COCKERELL & ELIOT, 1905

The brief original description of *Spurilla chromosoma* is based on a single specimen collected at San Pedro (Deadman's Island — no longer in existence). Although no figures are given, the text description is sufficient to distinguish it from other aeolids from the northeastern Pacific.

During the past several years a large number of individuals agreeing with the original description of *Spurilla chromosoma* has been collected in the intertidal regions of San Diego and La Jolla, and on boat landings in Mission Bay. Additionally, a few slugs have been identified from a protected yacht harbor at Newport. Although never abundant, specimens have been collected throughout the year.

This aeolid is one of the most common nudibranchs inhabiting those regions of the Gulf of California thus far investigated. Specimens have been collected at Bahía de la Paz, 17 III 1954, 8 slugs and nidosomes; Bahía de la Concepcion (7 III 1954, 6 slugs and nidosomes); Bahía de los Angeles (7 V 1961, 12 slugs and nidosomes; 14 IV 1964, common with nidosomes; 13 V 1964, common with nidosomes); Bahía San Luis Gonzaga (5 II 1966, common with nidosomes); four miles south of Puertecitos (20 III 1965, common with nidosomes); and San Felipe (28 XI 1965, 1 slug). This last record is of interest in that it represents the northernmost point in the Gulf of California from which a shell-less opisthobranch has been recorded.

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## Notes on the Mollusca of Prince William Sound, Alaska

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DURING THE LATER part of June and early July 1965, I had the opportunity to observe and collect marine invertebrates on and about Prince William Sound, Alaska. Prince William Sound is actually a northern extension of the Pacific Ocean and is separated from the sea by several major islands, between which open channels allow free passage and intermingling of sea waters. There are many islands and island groups around the periphery of this sound, and the mainland coasts are cut by numerous deep fjord-like bays and inlets, many of which are headed by active glaciers. A few days prior to my arrival in the area, a biologist working on temperature transects of this region noted a surface water temperature range from 8° C to 4° C (south to north), and on the freshwater lenses near the glaciers the temperature was 2° C. The tree line is between 800 and 900 feet above sea level, and the snow line was approximately 1000 feet above sea level during the time of my stay. The weather was wet, with many rain storms, as well as heavy mists, and at times strong winds, which forced small craft to shelter.

The southeastern portion of Prince William Sound was the area of major uplift during the earthquake of March 27, 1964; some localities were elevated in excess of 30 feet. It appears that the uplift occurred within the few minutes of tectonic activity, as dead specimens of various marine animals were found *in situ*, adhering to the rocky faces that in pre-earthquake times had been subtidal. It appeared that the animals did not have enough time to move downward and remain in the water as the water receded, or, actually, as the land moved upward. One interesting feature noted was several tree stumps, rooted in the substrate in what had been a subtidal level, and which now was elevated well above the present high-tide level at McLeod Bay on Montague Island. How long ago this forest lived above sea level, when it was submerged into the sea, and how long it remained submerged are questions that I cannot answer, but the emergence of the stumps above sea level is a very good indication of the instability of this region.

My guide was Mr. Rae Baxter, Shellfish Biologist, Alaskan Department of Fish and Game, with headquarters at Cordova, Alaska. I accompanied him on board the Department's research craft "Montague," a 24-foot modi-

fied "Doghouse Skiff," very similar to the fishing craft used by local commercial fishermen who drift floating gill nets. The "Montague" differed by being slightly wider, having a two-man cabin, and an enclosed wheel house. This small craft was our mobile home and field laboratory for three weeks as we moved about the islands, channels, and bays of Prince William Sound.

Upon our return we compared our observations and lists of specimens with the distributional lists of DALL (1921), EYERDAM (1924), OLDROYD (1924-1927), KEEN (1937), BURCH (1945-1946) and LA ROCQUE (1953). We found that with the exception of EYERDAM, there were little if any data pertaining to ecology, abundance, or paucity of the marine mollusks inhabiting this area. We also found that in our collections there were specimens representing species that had not been previously recorded from these northern latitudes, and some definite collecting localities for species which had previously been listed only as from "Alaska" or "Gulf of Alaska."

After considering the information as to distribution, ecology, and status of the marine mollusks of this region, we decided that it would be more appropriate if we confined our discussion to such information and covered taxonomic matters only where it was absolutely necessary. There is some confusion as to the proper taxa to be used on many of these northern mollusks, which may be due to lack of series of specimens in collections. It was found, not surprisingly, that in a number of cases a species varied from location to location, and even among individuals within a single population. The taxa used in this report are those of the authors listed above, with few exceptions. These will be explained as needed.

Both Mr. Baxter and I have made special studies of certain families of marine mollusks, and we considered it advisable for each of us to contribute portions to this report covering the groups with which we are more familiar. Thus, here only a few of the families of marine mollusks found on and about Prince William Sound and portions of the Kenai Peninsula will be covered. All localities mentioned may be found on Coast and Geodetic Survey Chart No. 8551.

Observations and collections were made along the east shore of Hawkins Island, Boswell Bay on Hinchinbrook

Island, Stockdale Bay, Port Chalmers, Hanning and McLeod Bay on Montague Island, Green Island and Channel Island in Montague Strait, Squirrel Island in the Knight Island Group, Eshamy Inlet and Falls Bay on the west mainland of the Sound and at Cedar and Well's Bay on the north shore of Prince William Sound. Dredging was carried out offshore of these stations.

## ARCHAEOGASTROPODA

### SCISSURELLIDAE

*Scissurella* are tiny, and rare to uncommon in collections. The exact status of certain taxa is uncertain, probably due to the lack of sufficient comparative material. In this discussion I will use the names applied by DALL for the two species he described from the Pacific coast. Both were taken in Prince William Sound, a northern extension of the published ranges.

*Scissurella kelseyi* DALL, 1905.

A few dead shells were dredged in 25 fms off Woodcock Point, McLeod Bay, Montague Island. The bottom in this locality appeared to be a sump and was composed of sand, mud, fine gravel, broken shell, and broken dead bryozoa. It is possible that living examples might have been taken in deeper water or perhaps in lesser depths on either rocks or alga holdfasts. A second location for this species was found in 25 fms off Cedar Bay on the north side of the Sound. Here the bottom conditions were very similar, but the bryozoa were lacking.

*Scissurella chiricova* DALL, 1919.

This species is distinguished from the preceding one by having weaker sculpturing and a more elevated spire. Specimens were taken in association with the first-named scissurellid off Woodcock Point. The species seems to be much rarer than *Scissurella kelseyi*, and we located no specimens that might be considered intergrades between the two.

### FISSURELLIDAE

*Diodora aspera* (ESCHSCHOLTZ, 1833).

This fissurellid was relatively common in suitable habitats, especially in the seaward area of Prince William Sound. There was nothing special to distinguish specimens of this species except a lesser size when compared with Puget Sound material. The largest specimen collected measured 51 mm by 36 mm.

*Puncturella noachina* (LINNAEUS, 1771).

Two specimens were dredged off Woodcock Point on Montague Island, in 17 fms, from a mud and small rock

bottom. MACGINITIE (1959) places this species as far south in the Pacific as Stephens Passage near Juneau, Alaska; Prince William Sound is actually north. Baxter has several records of this species from Port Dick on the Kenai Peninsula. The range of the species is circumboreal.

*Puncturella cucullata* (GOULD, 1846).

EYERDAM refers to this species from Drier Bay, Knight Island, Prince William Sound but did not specify if his specimens were dead or live taken. We found two specimens on the elevated shore at Woodcock Point. From the paucity of known specimens, this species appears to be rare in this region.

*Puncturella galeata* (GOULD, 1846).

This was the second most common species of the genus in the Sound. Baxter has records of this species from numerous stations. We took them living in the deep intertidal at Woodcock Point and as beach shells on all elevated terraces in the southern portion of the Sound.

*Puncturella cooperi* CARPENTER, 1864

(*P. eyerdami* DALL, 1924, syn.)

This paper is not intended to be a taxonomic discussion, but a few brief notes are here given for clarification. Most northern shells of the genus *Puncturella* are unworn, and even when relatively large in size have little adhering marine growth, plant or animal. Thus the finer detailed sculpturing is usually intact. CARPENTER's species, from southern waters, usually is overgrown, and the ultra-fine pores between the ribs seldom show. When Eyerdam collected the specimens submitted to Dall, the latter renamed the species, not realizing that he had unworn material. The species was dredged in several localities in the Sound, but at no place may it be called plentiful, as only one or two specimens per locality were collected.

*Puncturella multistriata* DALL, 1914.

This is the most common species of this genus in these waters. Living examples were taken at several localities on Montague Island, and dead shells were picked up on most of the elevated terraces, in windrows. As far as this genus is concerned the species may be classed as abundant in Prince William Sound.

*Puncturella* sp.?

Two examples, one living and one dead, were dredged off Cedar Bay in 25 fms, which appear to be a distinct species. However, until sufficient specimens are obtained for definite comparisons, I mention these shells here only to illustrate the abundance of species of *Puncturella* in this region.



## LEPETIDAE

It appears that few taxonomists will agree in all details as to the actual number of species and subspecies of *Lepeta* that may be found in the Gulf of Alaska. In this discussion I will refer to two species, which may or may not be correct. *Lepeta caeca* (MÜLLER, 1776) has been recorded by COWAN (1964) south of Prince William Sound, and by MACGINITIE (1959) south and west of the Sound. None of the materials collected in 1965, or in the Baxter collection match material of typical *L. caeca*, available for comparison from Norway and Frenchmans Bay, Maine. It is difficult or impossible to separate *L. concentrica* MIDDENDORFF, 1851 from *L. caecoides* CARPENTER, 1865, as the diagnostic features in any large series merge one into the other. I am not certain exactly what Dall meant with his *L. alba* DALL, 1869, or *L. a. instabilis* DALL, 1869, but MACGINITIE places both of these names in the synonymy of *L. caeca*.

In Prince William Sound, *Lepeta* were found living on the rocks from the post-earthquake mid-intertidal zone down to our deepest dredging, at 25 fms. They were not common, but a few to many could be collected at each station.

## ACMAEIDAE

*Acmaea mitra* ESCHSCHOLTZ, 1833.

Specimens were collected at all suitable locations, well within the range of the species.

*Acmaea pelta* ESCHSCHOLTZ, 1833.

Token sets taken, common at all suitable locations.

*Acmaea scutum* ESCHSCHOLTZ, 1833.

Common at all suitable locations.

*Acmaea fenestrata cribraria* CARPENTER, 1866.

As in the case of the above listed species, only token collections were made, until we reached the area which had an uplift of ten feet or more. At that time, a definite search had to be made for this species, which has a restricted ecological distribution. At the present time it appears that this species has been lost in the major uplift region, but as it still is plentiful in portions of the Sound, it may become reestablished in time.

*Acmaea digitalis* ESCHSCHOLTZ, 1833.

This was one of the species that I was especially interested in as the ecological habitat is restricted to the splash zone. No living specimens were found in the higher elevated shore lines, although numerous dead shells were found in the drift. A few living examples were eventually discovered along the rocky ledges of the "Hinge" region, and in due time the new intertidal splash zone will be repopulated.

*Acmaea paradigitalis* FRITCHMAN, 1960.

Specimens were collected at Boswell Bay, Hinchinbrook Island, at Stockdale Harbor and Port Chalmers, Montague Island, and at several localities on Hawkins Island, all in areas of lesser uplift (6 to 10 feet), but only dead shells were found in the areas of major uplift. The species is less common than on the northern California-Oregon-Washington coasts. This Prince William Sound population is a definite northern extension of the published range of the species.

*Acmaea persona* ESCHSCHOLTZ, 1833.

Found in close association with *Acmaea fenestrata cribraria*; not common.

*Acmaea instabilis* (GOULD, 1846).

The species was found living at only one locality, Woodcock Point, McLeod Bay, Montague Island. Two specimens, both on rock and both distorted, were collected. The palm-form kelp (*Postelsia*) was restarting in the low intertidal, but at the time of collecting, it had only covered a few ledges. The elevated pre-earthquake intertidal area was littered with the dead holdfasts of this type of kelp and many shells of this oddly shaped limpet were found, but, like the kelp and other forms which had been elevated, all were dead, yet many *in situ*.

*Acmaea peramabilis* DALL, 1872.

A few living specimens were collected at Woodcock Point and a few at Eshamy Inlet on the west side of the Sound on the mainland. All were taken from off rocky faces well below the low-low water.

*Acmaea* sp.?

At least three additional *Acmaea* were present in material from Woodcock Point, Montague Island, but definite identification is questioned. There was one tiny shell dredged in 17 fms, which matches a specimen of DALL's *A. aleutica* (= *A. apicia*). From the deep intertidal area, one tiny rose-colored specimen has the forward apex of *A. rosea* DALL, and there are two specimens of an undescribed species previously found only along the California-Oregon Coasts.

## MESOGASTROPODA

## LAMELLARIIDAE

*Lamellaria stearnsii* DALL, 1871.

DALL diagnosed two subspecies with overlapping ranges, so only the nominate name will be used. Comparison of Prince William Sound specimens with California material failed to reveal any major difference except size. The northern examples are somewhat larger. One living specimen was collected in association with, but not on, an



ascidian at Cedar Bay on the north mainland shore. Beach shell were taken in drift at many localities.

#### VELUTINIDAE

The literature available lists eight species of *Velutina* which may or may not occur in this region. Of course, some of these names may be synonyms, and there is little or no information on the soft parts. We found in the field that the differences of the soft parts were, in some cases, more important than the shells.

*Velutina velutina* (MÜLLER, 1776)

(=*V. laevigata* of authors)

Found in association with, but not on ascidians, usually on the bottom of a rock or on the rock faces of narrow crevices. The calcareous shell is covered by a periostracum, and there is definite cording on both. The animal is a uniform tan in coloration. This species is common in Prince William Sound.

*Velutina prolongata* CARPENTER, 1865.

This is the most abundant species of *Velutina* we found. The shell is thin and fragile, only slightly calcified. The animal is colorful, cream, with a rim around the foot and the two tentacles orange colored. There is a mottled black and white mantle around the shell. Living specimens were taken in association with, but not on, ascidians and in company with *V. velutina*.

*Velutina rubra* WILLETT, 1919

WILLETT described this species from Forrester Island, Alaska, and as far as I could learn, WILLETT's original lot and our Prince William Sound specimens are the only research material available. The shell is chitin-like and unless preserved in some liquid (such as alcohol + glycerin) the shell will disintegrate and crumble. The specimens were taken in association with scarlet ascidians, and the animal is brilliant scarlet. The animal is small for the shell. Collected at both Woodcock Point, Montague Island, and Cedar Bay on the north coast of the Sound.

#### EPITONIIDAE

*Epitonium greenlandicum* (PERRY, 1811).

Fragments which were identified as this species were found amid the elevated terraces at both Woodcock Point and on Channel Island (between Montague Island and Green Island in Montague Channel). Prince William Sound is within the range of this species.

*Epitonium indianorum* CARPENTER, 1865.

No living examples were taken in 1965, but Baxter has the species from several localities on the Sound. Two beach shells were picked up at Woodcock Point on Montague Island. EYERDAM (1924) does not list this species

from Knight Island and stated that he had not found the species on the Sound. Evidently it is rather uncommon.

*Epitonium* sp.? cf. *E. caamanoi* DALL & BARTSCH, 1910.

A single dead beach shell, picked up in a crevice at Woodcock Point, Montague Island, may or may not be this species. The original description is of a small shell, slightly less than 10 mm long. There is a specimen in the California Academy of Sciences that is about 12 to 15 mm long. The single specimen from the elevated beach on Prince William Sound matches in all details the description of *E. caamanoi*, except for size. Like the type, this specimen is truncated, but it is still 31 mm long.

*Opalia wroblewskyi* (MÖRCH, 1876).

Fragments and dead shells were dredged in Montague Channel, and specimens were obtained on the elevated reef at Channel Island. Baxter has taken this species at Port Dick, Kenai Peninsula, and Willett collected the species at Forrester Island, Alaska. *Opalia wroblewskyi* appears to be uncommon in collections, whereas the more southern *O. chacei* STRONG, is often labelled as the northern species. *Opalia wroblewskyi* is more slender, has the lower whorls unsculptured, and is much larger than *O. chacei*.

#### ACKNOWLEDGMENTS

At this time I would like to express my appreciation to the staff of the Alaskan Department of Fish and Game at Cordova, Alaska, for the cooperation and assistance given while I was in their area. Dr. G Dallas Hanna of the California Academy of Sciences gave encouragement in the field and answered several important geological questions, illustrating his answers by on-the-spot exhibits. Walter Eyerdam furnished much field collecting data. Dr. Joseph Rosewater of the United States National Museum and Dr. William Clench of the Museum of Comparative Zoology provided comparative material. Dr. Leo G. Hertlein of the California Academy of Sciences assisted in the comparison of certain Epitoniidae. Mr. James McLean of the Los Angeles County Museum made available his unpublished manuscript and illustrations of type specimens to clarify certain taxa. Mr. and Mrs. E. P. Chace of the San Diego Museum assisted by opening the collection in their charge for comparative purposes. To each and all of these, I extend my sincere thanks.

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## NOTES & NEWS

### Range Extension for

*Tylodina fungina* GABB, 1865 (Gastropoda)

BY

HELEN DUSHANE

15012 El Soneto Drive, Whittier, California 90605

THIS REPORT, the first of the occurrence of *Tylodina fungina* GABB, 1865 in the Gulf of California, Mexico, concerns a living specimen taken at Guaymas, January 7, 1966. The specific location where this shell was found is the north side of Punta Colorado, at a — 2.0 tide, at the water's edge on the underside of a rock. The animal had made a brilliant yellow spiral track on the face of the rock. The body was also brilliant yellow.

According to OLDROYD (Marine shells of the west coast North America, 1927, vol. 2, part 1), the type locality of this species is Santa Barbara, California. The typical range is from Santa Barbara to San Diego, California.

The single specimen measures 9 mm in length and 7 mm in width. The range extension is approximately 2660 kilometers from San Diego, California, to Guaymas, Sonora, Mexico.

### Erroneous Range Extension for *Tivela stultorum* (MAWE, 1823)

BY

HELEN DUSHANE

15012 El Soneto Drive, Whittier, California 90605

*Tivela stultorum* (MAWE, 1823) (Veneridae) has been erroneously reported from the Gulf of California, as a range extension. In *The Veliger* 4 (1): 22, *T. stultorum* was reported living at Bahía San Luis Gonzaga, 200 km south of the International Line, by Dr. Donald Shasky. He reported having seen living specimens at low tide on the sand spit west of Willard Island.

This fact was mentioned to Mr. Warren Garrett of South Pasadena who frequently flies his plane into Baja California. He said that he knew the man who transplanted loads of *Tivela stultorum* from San Quintín to Bahía San Luis Gonzaga. No further evidence regarding the presumably fallacious report was available at that time.

On a trip to Gonzaga Bay in February, 1966, I had the good fortune of meeting and talking with Mr. Charles Ceybert of Imperial, California, who had "created" the range extension. He confirmed Mr. Garrett's statement and elaborated on it by saying that he flew the clams in

from both San Quintín and Punta Canoa, and placed them at several locations along the shore. He claimed they survived a year. We found no living specimens in February 1966, although beach valves were fairly common.

A conversation with Mr. John Fitch, Research Director, California State Division of Fish and Game, revealed the normal range of *Tivela stultorum* to be from 19° to 36° North Latitude, from Punta San Juanico, Baja California, Mexico, to Monterey Bay (Santa Cruz), California. Mr. Fitch further stated that there had been frequent reports of the species from various points along the West Coast of Mexico. His own diving experience at these localities revealed only dead specimens on the bottom. It is his belief that the commercial fishermen bring the clams aboard for food and toss the empty shells overboard at various ports along the Mexican mainland. He said on his first trip to Bahía San Luis Gonzaga, about 1950, there were no *Tivela stultorum* present (J. Fitch, personal communication).

### Gift from San Diego Shell Club

THROUGH A GENEROUS donation by the San Diego Shell Club it was possible to include one of our recent halftone plates without having to charge its cost to the author.

We express our appreciation and that of the author for this gesture and wish to take this opportunity to call the attention of all interested readers to the fact that all donations to the California Malacozoological Society, Inc. are deductible for U. S. income tax purposes.

## Editor and Proofreader Apologize

Page 249, column 1: *Erosaria (Ravitronea) h. helvola*, insert between 3rd and 4th line after table –

the islands. The Philippine shells are a rich, deep caramel-  
Page 251, column 1:

The width of the smallest shell should read: 14.4 mm.  
Plate 41, Figure 46, read:

*Erronea cylindrica cylindrica* (BORN, 1778)

page 266, column 2: the 14th and 15th lines from the bottom of the page are transposed.

page 273, the last line should read:

Calif., no. 41: 14).

the present last line should be transferred to page 274 as line 7 in the entry for *Terebra larvaeformis*.

page 274, the first two lines of column 1 should be lines 8 and 9 of the entry for *Terebra larvaeformis*.

the present last line of the entry for *Terebra larvaeformis* should be deleted.

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\$12.80 all other foreign countries.

## BOOKS, PERIODICALS, PAMPHLETS

### Pesticides in Sea Water and the Possibilities of Their Use in Mariculture.

by VICTOR L. LOOSANOFF. Repr. from 'Research in Pesticides,' 1965, Acad. Press Inc., New York, pp. 135 - 145.

A review of the effect of pesticides used on dry land and reaching eventually the marine environment is given. In a summary of the work of this author and his co-workers, in which thousands of compounds were tested, it is shown that not all pesticides are harmful to marine organisms, though toleration varies, of course, from species to species. In this work it was also found that some pesticides were suitable for reducing the number of undesired organisms in cultures of algae for the feeding of molluscan cultures. However, the author emphatically cautions against the many dangers inherent in the use of pesticides.

RS

### Gonad Development and Discharge of Spawn in Oysters of Long Island Sound.

by VICTOR L. LOOSANOFF. Biol. Bull., vol. 129 (3); pp. 546 - 561; 6 text figs. December 1965.

Observations over a large number of years are reported. These are concerned with gonadal development (13 years), starting date of spawning in various localities (19 years), date of maximal discharge of spawn, date of completion of spawning and other details of oyster re-

production. That the information gathered is of great importance to the commercial oyster growers need not be stressed.

RS

### A Guide to the Mollusca of the Mediterranean in Israel

by AL BARASH & C. DANIN, - 168 pp., 22 figs., and 24 color plates — in Hebrew. Publ.: Sifriat Hasade, Tel-Aviv, Israel.

This small book (appr. 12 x 15 cm), written in Hebrew, summarizes many years of work by the authors on the molluscan fauna along the sea-shore of Israel. Its main purpose is to present a checklist of the common shells. The first part of this book deals with the problems of morphology and anatomy of the Mollusca, important for the determination of various systematic units. The second part lists the shells which are illustrated on the color plates incorporated in this book from that of Josette Arrecgros' "Coquillages Marins." The third part is a key to the common shells, at the end of which appears an alphabetical index of Latin names of all the species mentioned and a short bibliography of papers and books dealing with Mollusca.

L. Fishelson.

### Illustrations to "Catalogue of the Collection of Mazatlan Shells" by Philip P. Carpenter

by DORIS C. BRANN. Paleontological Research Institution, Ithaca, N. Y. Pp. 111, pls. 60. April 1, 1966.

The plates of camera lucida drawings that Carpenter prepared to illustrate his "Mazatlan Catalogue" have lain unpublished (except for a few figures on selected groups) for over a century. We owe a debt of gratitude to the Paleontological Research Institution for now making these available, for at last the illustrations of most of the microscopic forms are extant. The quality of reproduction is excellent. Although Carpenter was not an expert draftsman, the figures will be very useful in the interpretation of his species.

MK

### Neogene Mollusks from Northwestern Ecuador.

by A. A. OLSSON. Paleontological Research Institution. October 28, 1964. 236 pp., 38 pls. \$ 11.00.

Although dealing with a fossil fauna, this work has reference to the Recent; about thirty of the species are

known to be living. The plates are of excellent quality. Numerous new species are described, and 17 new generic taxa are proposed.

MK

#### A Survey and Illustrated Catalogue of the Teredinidae (Mollusca: Bivalvia)

by RUTH D. TURNER. Museum of Comparative Zoology, Harvard University, Cambridge, Mass. 02138. Pp. i - vii, 1 - 265; pls. 1 - 64. 1966. \$8.00 from the M. C. Z.

A more complete and informative catalogue of a molluscan family would be hard to imagine, for this work has a review of the fossil record, a discussion of anatomy of the soft parts and of functional morphology and physiology, as well as life history; notes on distribution and dispersal; the major groups in the Teredinidae and their evolution; guides for identification; summaries of generic characters and keys to the genera; and, finally, the catalogue proper, which lists and illustrates all known fossil and living Teredinidae. The figures are in the main original drawings made by the author from the type specimens she has studied in the museums of Europe and the United States, and the plate explanations carry notes that she has made about the specimens as she examined them. This "Survey" is a model of what a systematic catalogue should be.

MK

#### Catalogue of the Paleocene and Eocene Mollusca of the Southern and Eastern United States.

##### I. Pelecypoda, Amphineura, Pteropoda and Cephalopoda. II. Gastropoda.

by K. v. W. PALMER and DORIS C. BRANN. *Bulletins of American Paleontology*, vol. 48, no. 218, Pt. 1 June 25, 1965. Pt. 2, May 10, 1966; total pagination 1057, 5 pls. Price, \$16.00 (both parts).

This is an alphabetical list, in modern terms, of the Early Tertiary mollusks of the Atlantic seaboard. Full synonymies are included, with good cross-references to earlier usages. A glossary of stratigraphic nomenclature and a bibliography as well as a summary of the location of types is given in the first part. So comprehensive an index will be a boon to paleontologists over a much wider area than the title suggests. The authors are greatly to be commended for having put into print a work of this sort — sorely needed but rarely produced.

MK

#### Cretaceous Pelecypods of the Genus *Pinna* from the West Coast of North America

by EARL L. PACKARD and DAVID L. JONES. *Journ. Paleont.*, vol. 39, pp. 910-915, pls. 107, 108, 1 text fig.; September, 1965.

Six *Pinna* species are recognized in Cretaceous rocks from southern California to Alaska. All of them are described, two of them for the first time, and five are illustrated by excellent photographs. The Alaskan occurrences of two species of this characteristically warm-water genus contributes further evidence for a widely expanded Cretaceous tropical belt.

ECA

#### Jurassic Marine Faunal Differentiation in North America

by RALPH W. IMLAY. *Journ. Paleont.*; vol. 39, pp. 1023 to 1038, 6 text figs.; September, 1965.

Faunal differentiation of some Jurassic mollusks started on a worldwide basis near the beginning of Middle Tertiary time. Differentiation is shown mostly by ammonites and by the pelecypod genera *Buchia* and *Inoceramus*. Before differentiation began, the Jurassic molluscan faunas were cosmopolitan, or nearly so. After differentiation, the molluscan faunas, as reflected primarily in the ammonites, divided into three large but shifting geographic groupings which have been named by ARKELL the Boreal, Tethyan and Pacific realms. The ammonite faunas of the Boreal and Tethyan realms intermingled in California and Central Europe. The ammonite faunas of the Pacific realm intermingled with those of the Boreal realm in the Pacific Coast region of North America and in Japan. Elsewhere in the Pacific Ocean areas they intermingled with faunas of the Tethyan realm. Within the Pacific realm the characteristic ammonite genera at most places were outnumbered by ammonites of the other realms.

Latitudinal shifting of Boreal and Tethyan molluscan faunas occurred several times in the Pacific Coast region of North America. During the late Middle Jurassic ammonites of Boreal affinities extended southward into central California. During the late Jurassic, ammonites of Tethyan affinities dominated as far north as southwestern Oregon. In Eurasia similar faunal shifts occurred at approximately the same times and in the same directions. Such shiftings were probably related to regional changes in the marine connections between the oceans, but possibly were related also to changes in solar radiation.

The primary cause of faunal differentiation during Middle and Late Jurassic times probably was the general emergence of continents coupled with the development of physical barriers between the oceans. These events probably resulted in partial isolation and cooling of the Arctic Ocean and in changes in ocean currents that influenced the dispersal of organisms. Although most of the faunal differentiation is related to latitude, cooling of the Arctic Ocean was not a primary cause of differentiation, as shown by the fact that some differentiation occurred throughout the Jurassic seas of the Pacific Ocean area.

ECA

**Studi Geologici e Paleontologici su Capo Milazzo  
con particolare Riguardo al Milazziano**

by GIULIANO RUGGIERI and ANTONIO GRECO. Geol. Rom. vol. 4, pp. 41 - 88; 11 pls.; 4 text figs.

The stratigraphy of the peninsula of Milazzo is briefly discussed. However, the major part of the work is devoted to a study of a marine terrace with complete photographic documentation of the malacofauna found there. Although no new species are described, the work enumerates many species that are found in the Recent fauna of the Mediterranean.

RS

**Mega fauna of the Upper Miocene Castaic Formation,  
Los Angeles County, California.**

by ROBERT J. STANTON, Jr. Journ. Paleont., vol. 40, pp. 21 - 40; pls. 5 - 7, 2 text figs. January 1966.

The approximately 100 species, most of which are mollusks, recognized in collections from 50 localities in the vicinity of Castaic, indicate that Late Miocene conditions in that area of southern California resembled those found today in coastal areas of southwestern Baja California. No new species are described, but chronologic and geographic ranges of numerous species are extended on the bases of their occurrences in the Castaic Formation. Particularly noteworthy are northward range extensions of taxa with closest relatives characteristically parts of fossil and modern

Panamanian Molluscan Province faunas. These include *Glycymeris* cf. *G. gigantea* (REEVE), *Spondylus* sp., *Eu-crassatella* (*Hybolphus*) *subgibbosa* (HANNA), *Liotia carinata* CARPENTER, *Nerita* sp., *Trochita* cf. *T. trochiformis* (BORN), *Polinices uber* (VALENCIENNES), *Pyrene* sp., *Oliva spicata* (RÖDING), *Marginella* cf. *M. albuminosa* DALL, and *Conus* sp.

ECA

**Studies of Opisthobranchiate Mollusks  
of the Pacific Coast of North America.**

by FRANK MACE MACFARLAND. Memoirs Calif. Acad. Sci., vol. 6; xvi + 546 pp., 72 pls. of which 28 in color. Price: \$17.50 at the Calif. Acad. Sci., San Francisco.

The 28 color plates with their respective explanations are available separately at \$3.50. California residents are no doubt aware that state sales tax has to be added.

This luxuriously produced work, posthumously published, will be received with great joy by all students of opisthobranch mollusks, here and abroad.

When Dr. MacFarland died on February 21, 1951, he left a large manuscript for which his talented wife had drawn and painted a very large number of magnificent illustrations. After many delays, this important work appeared on April 8, 1966. It is not surprising that some of the species described in this monograph as new have, in the more than 15 years since the manuscript was laid aside, been discovered by other students and described. The editors of the book were well aware of this fact but – we think – wisely decided to publish the descriptions by MacFarland as they stood. There can be no doubt that any species which has been named and whose MacFarland name thus has become a junior synonym, has not been described better or been illustrated more comprehensively than it is done in this work. It may be expected that in the not too distant future such corrections as may seem desirable will be made, thereby bringing this monograph abreast of modern knowledge of this interesting and attractive group of mollusks.

RS



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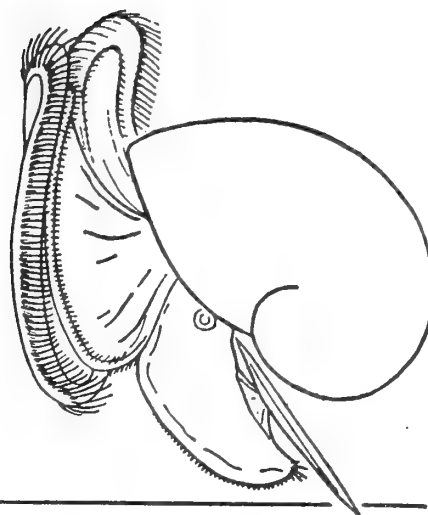
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

**ORDER**, Suborder, **DIVISION**, Subdivision, **SECTION**,  
 SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).  
*New Taxa*

## LINNAEUS' Type Specimens of Cowries

BY

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THE COWRIE SHELLS belonging to the collection of LINNAEUS are preserved in the cabinet of the Linnean Society of London. They have been discussed twice in detail, viz. by HANLEY (1855) and by DODGE (1953). However, both conchologists have restricted their studies to investigations into the specific identity of Linnaeus' specimens with the species credited by later writers to be the species established by Linnaeus. HANLEY compared Linnaeus' shells with illustrations in then modern monographs, as of SOWERBY (1828, 1832-1837), KIENER (1843-1845), REEVE (1845-1846), etc., and DODGE compared recent microfilm reproductions of the specimens preserved in the Linnean Society of London with shells which usually are named with specific names established by Linnaeus, with exhaustive remarks on bibliography, taxonomy, etc., of each species. But generally neither HANLEY nor DODGE published the measurements and exact descriptions of the specimens which would allow to recognize the variety or even the geographical race (SCHILDER & SCHILDER, 1938 to 1939) to which Linnaeus' shells belong.

In March 1936 I was permitted to study the cowries of Linnaeus then preserved in the cabinet of the Linnean Society of London: each specimen belonging to Triviacea (Triviidae) and to Cypraeacea (Cypracidae and Ovulidae) has been carefully examined with regard to the probability that it might belong to Linnaeus' original type specimens; and each shell has been measured accurately and described in exhaustive notes, especially with regard to characters which point to its belonging to a geographical race or ecological variety. Now, after 30 years, when approaching my seventieth birthday, I think that it is high time to publish these data so that Linnaeus' type specimens will be described as accurately as necessary; I think that these descriptions of essential details will explain the individual characters of the shells in a better way than the most exact photographs could do.

For though we cannot be absolutely sure that the specimens preserved in Linnaeus' collection really are the same shells which Linnaeus faced when he composed his descriptions, there is a probability in different degrees that it was so. Several species rare in Linnaeus' time are

represented by only one specimen in his cabinet, other descriptions agree with a specimen in such a way that it is most improbably a later replacer for a similar shell removed from the collection. HANLEY has added the specific names cut out from his publication (1855); besides, many shells wear a pasted oval label (about 1 cm across) which is inscribed with a number in very antique figures: these figures evidently written by Linnaeus himself mostly correspond to the number of the species enumerated in the 12th edition of his *Systema Naturae* (1767), some few to the tenth edition (1758) while several other figures are incomprehensible.

According to art. 61 and to recommendation 73 A of the International Rules of Zoological Nomenclature it seems to be desirable that type specimens of all species should be fixed; this tendency chiefly refers to the species established by LINNAEUS and LAMARCK which often have been divided into several species or subspecies by later authors. Therefore I selected from Linnaeus' specimens the most fitting shells as type specimens, and I propose to treat and label them as holotypes (art. 73 a), lectotypes (art. 74 a), or neotypes (art. 75) respectively:

a) If there is only one specimen of a species preserved in Linnaeus' cabinet it should be treated as a **holotype** even if the oval label is missing.

b) If there are two or more specimens which most probably were represented in the cabinet in Linnaeus' times, the specimen most closely fitting in characters and condition should be selected as **lectotype**, in any case a shell wearing the oval label; the other shells may or may not be called paralectotypes (art. 74 E).

c) If there are several specimens which may or may not be Linnaeus' original shells, the most fitting specimen should be selected as **neotype**, as it is more probable that Linnaeus described the species using as prototype one of these specimens than a shell preserved in a foreign collection, though there is one exception: therefore, if one decides to select a neotype, one should prefer a shell preserved in Linnaeus' collection rather than a shell preserved elsewhere.

In the following paragraphs, the cowrie species established by Linnaeus have been arranged according to the numbers added in the twelfth edition of *Systema Naturae* (1767) followed by the two species published only in the *Mantissa* (1771). In the heading the name given by LINNAEUS is followed by the numbers added both in the tenth (1758) and the twelfth (1767) edition. The description of each species begins with the proposed typological status, and, where applicable, the number entered on an oval label; it is followed by the generic and specific name used in our recent papers, and a formula indicating size, shape, and dentition, e.g. 755/58 38:34, in which 755 indicates the length in tenths of a mm (i.e. 75.5 mm), 58 the breadth in per cent of the length, 38 the number of labial teeth, and 34 the number of columellar teeth, the anterior columellar ridges excluded.

*Cypraea exanthema* (—, 325)

Lectotype (label 325): *Macrocypraea zebra* syn. *exanthema*, 755/58 38:34, spire projecting, columellar teeth short, fossula and columellar sulcus well developed; fawn, hardly darker around the spire, spots large, white, the lateral ones with a reddish brown center.

Second shell: 760/51, color more saturate, spots smaller.

*Cypraea mappa* (285, 326)

Lectotype (label 326): *Mauritia mappa*, 685/60 36:29, margins and base rather callous, inner lip acuminate and bent to the left on the rear; dorsal markings regular, of medium shade, spire blotch very large, lateral spots scarce, the right ones rather large and dark brown, the left ones smaller and paler, base very pale pinkish, columellar central blotch large, pale, purplish grey, but very distinct, teeth orange within the aperture only. The shell probably belongs to the Pacific race.

Second shell: 807/64, very similar, but still more callous, lateral spots large, base suffused with pink, columellar blotch and aperture more vividly colored. The shell is rather fresh so that it possibly has been added after Linnaeus' time.

*Cypraea arabica* (286, 327)

Lectotype (label 327): *Mauritia arabica*, 699/59 34:30, outer lip narrowly margined, base flat, terminal ridge oblique; dorsal striae prevailing over the pale lacunae, spire blotch absent, lateral spots rather small, base pale flesh color, teeth rusty brown. The shell evidently belongs to the Indian race called *dilacerata* SCHILDER & SCHILDER (1939, p. 183).

Second shell: 655/60, dorsal striae more dilacerate, pale, lateral spots scarce; evidently also *dilacerata*.

Third shell: 580/59, more saturate, dorsal striae and lacunae rather confused, lateral spots much larger; the shell recalls the Malayan and Pacific races of *arabica*.

*Cypraea argus* (287, 328)

Holotype (no label): *Lyncina argus*, 827/51, subzonate, dorsal rings very distant, mostly small with few larger and thicker (but not doubled) ones intercalated; the base and the teeth could not be examined as the shell is fastened to the tray.

*Cypraea testudinaria* (288, 329)

No specimen was represented in LINNAEUS' collection, even not in HANLEY's time (1855).

*Cypraea stercoraria* (289, 330)

Holotype (label 330): *Trona stercoraria*, 592/63 30:22 (two terminal ridges and two intercalated anterior ribs excluded), rather oblong, right margin narrow and acutely margined, fossula very broad and concave, ribbed, with 9 inner denticles, columellar sulcus narrow, ribbed; dorsal spots small, slightly confluent but distinct, spire blotch rather large, lateral spots small, rather confused and suffused with grey. The shell the anterior extremity of which is damaged, evidently belongs to the oblong, basally flattened ecological variety called *conspurcata* (GMELIN) in my papers.

*Cypraea carneola* (290, 331)

There are five shells which HANLEY (1855, p. 183) declared not to be LINNAEUS' types; nevertheless, I propose to select the

Neotype (no label): *Lyncina carneola*, 327/64, rather deltoidal with thickened margins, greyish red with a distinct lilac ring.

Two other specimens (250/70 and 373/63) are very similar in shape and color, and a fourth (380/64) is a younger shell of the same small callous variety, while a fifth shell (695/60) which is quite calcified by the well known "disease" of old, not ventilated shells looks rather like *Lyncina leviathan* SCHILDER & SCHILDER.

*Cypraea zebra* (291, 332)

Lectotype (label 332): *Macrocypraea zebra* (i.e. a young stage of *exanthema*), 751/54 (31):36, spire very projecting, fossula very broad and concave, but still rather smooth, columellar sulcus still very shallow but crossed by very regular ribs, the terminal labial teeth are not yet developed; pale grey with purplish grey-brown zones, outer lip becoming fawn, teeth dark brown.

A second shell (760/56) is slightly less young, as the fossula is ribbed, shell thinner, paler, more yellowish.

The characters of the spire, the fossula, and the columellar sulcus prove both shells to be juvenile stages of *exanthema* and exclude them from being young *cervus* (LINNAEUS) or *cervinetta* (KIENER).

*Cypraea talpa* (292, 333)

Lectotype (label 333): *Talparia talpa*, 707/48 47:38 (plus 5 ribs within the posterior outlet), right side narrowly margined, fossula very broad, ribbed, but with the inner denticles hardly thickened, columellar sulcus narrow in front, but obsolete behind; dorsum with four rather saturate zones, base dark chestnut.

A second shell (812/51) bears no label.

*Cypraea amethystea* (293, 334)

Lectotype (label 334): *Mauritia arabica*, 485/62 30:24, right margin thickened, but base flattened, aperture narrow, dilated in front, hardly curved behind, terminal ridge obliquely produced, central columellar teeth rather produced; dorsum ground and polished so that it became violet (brownish in the centre) and the usual striae and lacunae are hardly recognizable above the margins, but the spire blotch evidently was absent; lateral spots blackish, numerous, large but not confluent, base yellowish white, teeth rusty brown. The thickness of the margins (more approaching the Pacific race than the Indian *dilacerata*) prove *amethystea* (incorrectly spelled *amethystina* by HANLEY) to belong to *arabica* and not to *histrio* (GMELIN), as I conjectured from the figures and habitat indicated by LINNAEUS (see SCHILDER, 1966, p. 199, note 7).

The second shell (with an oval label without number) must not be regarded as paralectotype as it totally lacks the typical character which consists in the violet dorsum: it is a *Mauritia arabica*, 422/65 25:25 with similarly thickened margins, and slightly convex base; the dorsum, however, shows the rather dark striae and pale lacunae, but no spire blotch, the lateral spots are similar to the lectotype, but more confluent, base pale yellowish. This shell which evidently belongs to the Malayan-Pacific race of *arabica*, may have been added erroneously to the lectotype which should be better called holotype.

*Cypraea lurida* (294, 335)

Holotype (no label): *Luria lurida*, 370/59 (teeth not countable as the shell is fixed on the tray), pyriform, quite calcified so that the color is no longer recognizable; but the shell undoubtedly is a not fully grown specimen of the Mediterranean race *lurida*.

*Cypraea vanelli* (295, 336)

Holotype (label 336 in very old ink): juvenile *Lyncina lynx*, 255/62 24:19, labial teeth very short; dorsum greyish white, with irregular fulvous brown specks and spots which partially are arranged in transverse rows, terminal spots still indistinct, interstices of columellar teeth brownish orange.

*Cypraea lota* (296, 337)

The only specimen (label 337) should not be regarded as holotype, as HANLEY (1855, p. 185) stated that LINNAEUS' type specimen is preserved in the Dronningen Museum at Uppsala. The London specimen is a juvenile *Erosaria spurca*, 229/65 20:14, spire slightly projecting (three whorls and three and a half subsequent whorls), labial teeth very short, saw-like, columellar teeth short, nodulous (the terminal ridge and the hindmost rib excluded), fossula without inner denticles; very pale yellowish, margins with one row of rusty yellow spots. The shell is very similar to *Bulla cypraea* (see below).

Two other juvenile shells of *Erosaria spurca* (length 233 and 269, brownish fulvous) seem to have been put in the box later on.

*Cypraea fragilis* (297, 338)

Neotype (no label): juvenile *Mauritia arabica*, 441/62 30:24 (+ 4 denticles along the posterior outlet), cylindrical, teeth obsolete, hardly countable; greyish white with fulvous brown zones of usual shape. This junior shell evidently belongs to *M. arabica* (probably the Indian race *dilacerata*) as no other *Mauritia* agrees with its characters.

A second shell (380/62) is similar in shape, but totally calcified.

*Cypraea caput serpentis* (298, 339)

Holotype (label 298): *Erosaria caputserpentis*, 323/74 17:13, normally dilated specimen with the base flattened, but showing a rounded callosity in the center of the inner lip, aperture narrow, slightly curved behind; dorsum with white dots partly confluent to stars, posterior extremity orange, margins dark brownish grey, outer half of the base yellowish grey, inner half and the interstices of teeth white. Probably belonging to the Malayan race.

Two other shells (339/77 and 342/75) are paler fawn and evidently have been put into the box at a later date.

*Cypraea mauritiana* (299, 340)

Lectotype (label 340): *Mauritia mauritiana*, 703/72 27:22 (two terminal ridges and one intermediate rib

excluded), structural characters normal; dorsum with large lacunae (exposing the zigzag zones of the penultimate layer) and a central dorsal line, sides horny brown, edges and base greyish black, teeth dark chestnut, but becoming pale orange within the aperture.

A second shell which bears the label 34... in very old figures, is a young *Mauritia mauritiana* 515/62, with the margins still pale brown, the base greyish fulvous, and the teeth just beginning to become orange; it could be regarded as paralectotype, but LINNAEUS' description fits the lectotype only.

*Cypraea vitellus* (300, 341)

Lectotype (label 341): *Lyncina vitellus*, 422/66 26:20, base rather callous; dorsum greyish brown, with normal white spots, the lateral striae cross two thirds of the dorsum. The shell recalls the Malayan race.

Paralectotype (label 341): 408/63 2+24:20, not fully grown and rather more pinkish brown than the lectotype.

*Cypraea mus* (301, 342)

No specimen was represented in LINNAEUS' collection, evidently not even in HANLEY's time (1855).

*Cypraea tigris* (302, 343)

Lectotype (label 343): *Cypraea tigris*, 706/71 24:23 and the

Paralectotype (label 343): 697/69 25:23, both are almost identical with regard to the thickened, angularly callous margins and their color: dorsum yellowish white, with brownish black spots of medium size, which are surrounded by rusty and greyish blue shadows, dorsal line reddish brown. They recall Pacific varieties. The selection of the lectotype is quite arbitrary.

*Cypraea lynx* (303, 344)

Lectotype (label 344): *Lyncina lynx*, 280/61 1+20:15, regularly ovate with the extremities attenuated, sides thickened but not margined, basal carina of the inner lip well developed; dorsum pale fulvous with confused purplish brown and rusty brown spots, suffused with a thin layer of purplish pink enamel, pale dorsal line indistinct, margins white with scarce dark spots, interstices of teeth orange.

This adult *Lyncina lynx* marked with the label 344 was in the same box as the holotype of *vanelli* marked with the label 336 (see above); besides, in another box, there were two additional adult *L. lynx* and two young shells, all without oval labels; they may be described as

Second shell: 368/61 22:21, callous, margined, dorsum pale fulvous with normal spots, suffused with greyish pink, and

Third shell: 505/48 25:20, subjunior, margins rounded, dorsum orange, rather confused, with irregular large blackish blotches.

The two junior shells measured 327 and 343.

*Cypraea isabella* (304, 345)

Lectotype (label 31): *Luria isabella*, 260/59 32:25, base callous, fossula concave with 7 inner denticles, columella smooth; dorsum fulvous with several rufous interrupted striae, margins white (reaching about one third of the dorsum), extremities with four distinct orange red spots without any trace of dark centers. Therefore the shell evidently belongs to the Indian race called *lemuriana* by STEADMAN & COTTON (1946).

There are also five shells with similar characters: 197/54 (anterior orange spots confluent), 200, 237 (subjunior), 280/56 (dorsal striae blackish), and 339; but they seem to have been added at a later time.

*Cypraea onyx* (305, 346)

Holotype (no label): *Erronea onyx*, 377/60 20:17, central part of the dorsum whitish (with three greyish zones shining through), surrounded by narrow pale chestnut bands which are separated by a pinkish grey zone from the dark chestnut margins of the shell, base almost black. These characters unmistakably point to the Malayan race *onyx*.

*Cypraea clandestina* (—, 347)

Neotype (no label): *Palmadusta clandestina*, 173/61 20:16, labial teeth produced over more than one third of the lip, columellar teeth only to one quarter, fossula vertical, crossed by wedge-shaped ribs which are not thickened on its inner border, columella smooth in the rear; dorsum with the usual tortuous yellowish grey markings and traces of orange zigzag lines, extremities white.

Three other shells possibly have been added at a later time: 177/62 20:16 (with much produced teeth and 2 or 3 fossular denticles), 129/63 and 178/61 (both with distinct zigzag lines), all with white extremities.

*Cypraea succincta* (306, 348)

According to HANLEY (1855, p. 189, pl. 5, figs. 1-2) the holotype is preserved in the Dronningen Museum at Uppsala; the figure shows a very young shell (with only few anterior columellar teeth developed as nodules), about 400/62, blackish with two pale narrow zones. Now I think it to be more probably a young shell of the Malayan *Erronea onyx* (see above) than of the more western race *adusta* (LAMARCK).



*Cypraea ziczac* (307, 349)

Neotype (no label): *Palmadusta ziczac*, 179/61 22:18, outer lip damaged during the animal's life and healed, fossula vertical, narrow, crossed by wedge-shaped ribs without inner denticles; dorsum with regular fulvous zigzag lines and four very narrow transverse zones, lateral and basal spots almost black, base rich orange.

Second shell: 209/60 22:18, differs by the zigzag lines between the two central zones becoming rather short and straight almost as it is in *misella* (PERRY), and by the right margin showing a blackish longitudinal band.

Two further shells (length 150 and 158) show the zigzag lines as in the neotype, but in the former shell (150) the lateral spots coalesce.

*Cypraea hirundo* (308, 350)

Neotype (no label): *Bistolida hirundo* (with the synonym *neglecta* SOWERBY), 149/59 21:18, teeth produced across three quarters of the base, fossula rather broad, concave, ribbed, the columellar sulcus is hardly less broad, with faint transverse ribs and distinct inner denticles; dorsum greyish blue, with a distinct pale S-shaped anterior lacuna, whereas the posterior transverse band is obsolete and the pale round spot above the anterior extremity is absent; the brown dorsal dots are obsolete and a central blotch is entirely absent, lateral spots small and scarce (twelve on the right margin), four blackish terminal spots well developed.

Two other shells (129/54 and 132/53) are rather similar, but the former is rather greyish purple.

No *hirundo* of SOWERBY (1837) is represented among Linnaeus' shells at all, so that renaming it *kieneri* by HIDALGO (1906) was justified.

*Cypraea asellus* (309, 351)

Neotype (no label): *Palmadusta asellus*, 182/55 18:15, right side slightly margined and obsoletely pitted, six posterior columellar teeth much produced and swollen at their outer end, fossula rather vertical, ribbed, with inner denticles, columellar sulcus shallow, ribbed, with nodules within too; the three dark dorsal zones are rather narrow, suffused with greyish lilac and bordered by reddish brown zones, and crossed by white lines.

Four other shells are rather similar: 131 (with very narrow zones), 136/54, 145, and 175 (with slightly broader zones).

*Cypraea errones* (310, 352)

Lectotype (label 22): *Erronea errones*, 272/56 13 (+ a slight swelling behind): 15, base flattened, aperture wide, fossula reduced; dorsum pale grey, hardly zonate, with crowded fulvous specks and a large central blotch,

anterior extremity with two blackish spots (the right spot is rather large, the left smaller), a narrow marginal zone and the base are very pale yellowish white.

There are five other specimens which evidently have been added later on: 211, 246/57, 251, 256/55 (subjunior), and 256; they represent various varieties concerning the dorsal blotch, the terminal spots, and the color of the base, but all shells are typical *Erronea errones*, and no specimen of *ovum* (GMELIN) is represented among Linnaeus' specimens so that the renaming by IREDALE (1935) was unnecessary.

*Cypraea cribraria* (311, 353)

Neotype (no label): *Cribraria cribraria*, 255/59 22:21 (+ 2 denticles on the left wall of the posterior outlet), cylindrical, right side sharply margined, but slightly thickened, base callous, fossula and columellar sulcus regular, vertical, ribbed; dorsum reddish fulvous with regular large round lacunae, no dorsal line nor traces of lateral spots.

Two other shells are very similar: 202/55 (rather oblong-ovate) and 219/54 19:20 (base not callous, the damaged outer lip became healed by the animal).

*Cypraea moneta* (312, 354)

The label 312 in the box seems to refer to six specimens, but only one shell has a special label attached, and this shell should be regarded as

Lectotype (label 23): *Monetaria moneta*, 192/73 11:10, ecotype R (SCHILDER & SCHILDER, 1937, p. 1122), deltoidal, lateral tubercles low, aperture narrow, dilated in front, columellar teeth distinctly produced, but not tuberculate; the shell is rather worn, pierced behind the anterior extremity so that it evidently has been used as ornament by natives.

The other five shells (paralectotypes) represent different ecological varieties: 231/75 11:11 (ecotype RM, margins more callous, lateral and basal tubercles more accentuated, aperture narrow, orange ring distinct), 271/75 (ecotype M, similar to the preceding shell but the lateral tubercles become oblique ridges, ring vivid), 246/71 (ecotype ME, also similar, ring distinct though the shell is rather suffused with fulvous enamel), 164/70 (ecotype EC with the lateral and basal tubercles much projecting), and 168/66 11:10 (ecotype CR, margins callous, basal ribs short, not tuberculate, ring absent); all these shells look Malayan or Pacific, not Indian.

*Cypraea annulus* (314, 355)

Lectotype (label 314 in very old ink): *Monetaria annulus*, 255/73 15:13, ecotype A (see SCHILDER & SCHILDER, 1937, p. 1120), margins callous, base slightly

convex, aperture rather narrow, but dilated in front, teeth short; greyish fulvous, dorsal ring distinct; the shell evidently belongs to the Malayan race, but never can belong to the East African *camelorum* (ROCHEBRUNE).

Four other shells, viz. 215/60 (oblong), 225, 255 and 270 probably belong to the Malayan race also.

*Cypraea caurica* (313, 356)

Neotype (no label): *Erronea caurica*, 262/70 13:13, margins swollen, aperture rather narrow, slightly dilated in front, teeth crossing the base almost to the outer margin, posterior tip of the inner lip acuminate, fossula not concave, but crossed by strong ribs as it is in *E. pallida* (GRAY), columella ribbed without any sulcus; dorsum slightly zonate, with pale reddish brown specks, but no central blotch, margins whitish with pale distant spots, base pale orange, teeth whitish. The shell recalls the Ceylonese race.

A second shell: 249/63 15:16 is rather similar, but with the margins less thickened, the aperture wider, and the teeth less produced; color very similar.

Three further shells, viz. 320/58 (calcified), 315/54, and 347/50, show a large dorsal blotch which has not been mentioned in LINNAEUS' description; therefore they evidently came from another source.

*Cypraea erosa* (315, 357)

Lectotype (label 25): *Erosaria erosa*, 336/63 19:13, right margin broadly swollen so that the lateral pittings become obsolete, labial teeth crossing the lip, but columellar teeth restricted to the edge of the aperture, terminal ridge slit longitudinally, fossula with four inner denticles; dorsum reddish fulvous, with very small and rather close white specks, but hardly any brown spots, dorsal line bluish grey, the greyish lateral blotches are large, but the reddish brown lateral striae are hardly continued to the margins of the base.

Four other shells, viz. 220/61 and 280/59 (both without lateral blotches), 233/71 and 324/65 (calcified) are less callous so that the lateral pittings become well developed; they should not be regarded as paralectotypes.

*Cypraea flaveola* (320, 358)

Lectotype (no label): *Erosaria labrolineata* (GASKOIN), 139/59, brownish fulvous with distinct lateral spots, and

Paralectotype (no label) of the same dimensions 139/59, slightly calcified, reddish brown with obsolete lateral spots: both shells show white dorsal spots (without any dark centers nor rings), blackish lateral spots and four larger dark brown terminal spots, base white.

According to HANLEY (1855, p. 193) these two shells were the only specimens among Linnaeus' nameless shells

which agreed with the very short description of *flaveola* in 1758, and Linnaeus said to possess the species. Therefore there is no reason to reject the name *flaveola*: it must be used for the species also called *labrolineata* (GASKOIN, 1849), *helenae* (ROBERTS, 1869), and *nashi* IREDALE (1931) by later writers. The specific name *flaveola* (LINNAEUS, 1758) must be restored, as REEVE (1846) did, for art. 23 b of the rules cannot be applied against this procedure, since the name *flaveola* in the sense of LINNAEUS' tenth edition (1758) has been used by several authors after ROBERTS (1885), e.g. by ABRARD in 1946. The confusion arose from the fact that the more accurate description of *flaveola* published by LINNAEUS in 1764 refers to another specimen (probably preserved in the Museum of "Ludovica Ulrica") which belongs to *helvola* (see below), but not to LINNAEUS' type specimens of 1758.

*Cypraea spurca* (317, 359)

Neotype (no label): *Erosaria spurca*, 289/64 21:15, shape typical as in the Mediterranean specimens; dorsum reddish fulvous, the semilunar whitish spots rather confused, lateral spots and pittings dark brown, base bleached fulvous.

Four other shells (281, 282, 291, 298) are very similar to the neotype which is the central shell of the five specimens fixed on the wooden tray.

*Cypraea stolidia* (318, 360)

Holotype (no label): *Bistolida stolidia*, 199/53 20:17 (+ 1 denticle), cylindrical, columellar teeth produced (only the five anterior ones are short), fossula broad, ribbed, columellar sulcus ribbed in front and with a row of internal nodules in the rear; central dorsal blotch divided into two perforated parts (the right part of which is smaller) and not connected with the four rather obsolete lateral spots; teeth brown.

Though the dorsal blotch is separated, the shell evidently belongs to the Malayan race.

*Cypraea helvola* (316, 361)

Neotype (no label): *Erosaria helvola*, 212/76 16:14, rather broad, fossula with four denticles; dorsum with white specks and brown spots each covering about half the dorsal area, longitudinal lateral chestnut zones rather narrow, extremities pale purple, marginal edges and base orange.

Four other shells are rather different: 152/63 is a younger shell, in 176/75 (calcified) and 209/72 the white specks are prevalent, while in the oblong darker 246/62 20:17 the brown dorsal spots prevail.

*Cypraea ocellata* (319, 362)

Neotype (no label): *Erosaria ocellata*, 182/70 14:13, right margin swollen but pitted, base rather flattened; dorsum reddish fulvous, almost half of the white specks exhibit a dark center, lateral spots and basal striae reddish brown.

A second shell (198/65) is darker yellowish brown, and a third shell (206/63) shows a monstrosity consisting in the swelling of the columellar margin like that figured in the *Journal of Conchology*, volume 20, plate 9, figure 3 (1936).

*Cypraea poraria* (321, 363)

Lectotype (label 36 . . .): *Erosaria poraria*, 195/68 21:16, deltoidal with the extremities attenuated, fossula broad, concave, ribbed, columella smooth; dorsum reddish fulvous-brown, the pure white specks are about as numerous as the annulated ones, margins and base lilac, teeth white.

Three other shells (117/64, 190/67, 193/71) are very similar and evidently came from the same source. The deltoidal shape proves their coming from the Pacific, so that the eastern race *scarabaeus* (BORY, 1827) becomes a synonym of *poraria* and the ovate Indian race must be called *wilhelmina* (KENYON, 1897).

*Cypraea pediculus* (322, 364)

The tray (no label) contains 14 specimens three of which cannot be determined as they are fixed by the dorsum; the remaining 11 shells belong to three species:

Neotype: *Pusula pediculus*, 146/73 20:21 (with 69 ribs around the shell and 28 ribs starting from the dorsal sulcus in all directions), the smooth, slightly sinuous dorsal sulcus is bordered by two rows of nodules (many dorsal ribs die out before they reach the sulcus), fossula broad and deep, columellar sulcus narrow, but regular; dorsum pale greyish with three pairs of dark blotches, margins pink, base greyish pink, columella white within.

Five other shells (109, 109, 113, 116, 135) are very similar in structure, but some of them are slightly paler: they belong to the East American *Pusula pediculus* also.

Four shells, however, belong to the West European *Trivia monacha* (DA COSTA, 1778); 116 (with 34 dorsal ribs) and 104 exhibit three dark spots on the dorsum, and 91 (with 36 dorsal ribs) and 82 show two spots only. but in all four shells the dorsal sulcus is obsolete.

The last shell belongs to the anatomically different West European *Trivia arctica* (MONTAGU, 1803): 81.5 (with 31 dorsal ribs), dorsum unspotted, dorsal sulcus absent.

In 1767 LINNAEUS separated these three species by the terms *indica* (= *pediculus*), *europaea* (= *monacha*)

and *anglica* (= *arctica*); later writers disagreed as to whether these terms should be regarded as varietal names given by ternary nomenclature like those of the races of man, or only as geographical characteristics. Now I think them to be valid names: but *indica* becomes a synonym of *pediculus* in any case, and the other two varietal names should be rejected according to art. 23 b of the Rules (waiting period of 50 years).

*Cypraea nucleus* (323, 365)

Lectotype (label 32 . . .): *Nuclearia nucleus*, 255/60 27:17 (two terminal ridges, two intermediate ribs, and three denticles on the rear excluded), hardly rostrate (body whorl without extremities = 205), dorsum with rather scarce small tubercles (connected by ribs) and a rather sinuous longitudinal sulcus, base ribbed (only one columellar rib does not attain the aperture), fossula broad, ribbed, columella ribbed only externally; unicolored dirty pale greyish.

Second shell: 197/59, very similar, dirty brownish grey.

*Cypraea staphylaea* (324, 366)

Neotype (no label): *Staphylaea staphylaea*, 155/61 22:16, extremities produced, dorsal granulation fine, longitudinal sulcus distinct, base crossed by ribs to the margins; dorsum yellowish brown, extremities brownish red, base pale brownish.

Three other shells, viz. 136/60, 139/69 (deformed), and 162/60 agree with the neotype in structure; their dorsum varies from greyish brown to chestnut.

*Cypraea globulus* (325, 367)

Three shells were fixed on the wooden tray originally, but the central one was missing in 1936; the shell showing the base should be regarded as

Neotype (no label): *Pustularia globulus*, 153/61 29 (three of which are within the outlets): 17(+3 posterior denticles), subcylindrical, extremities short (the body whorl without extremities measures 123), dorsum smooth, labial teeth crossing  $\frac{1}{2}$  lip in the center and  $\frac{5}{8}$  lip behind, columellar teeth rather short in front and crossing  $\frac{1}{3}$  lip in the center; dorsum orange fulvous, punctate with brown, but destitute of central blotches, base orange, without any trace of blotches, teeth brownish.

The second shell (dorsal view): 159/62 (body whorl 129) is very similar in shape and coloring.

*Cypraea cicercula* (326, 368)

Neotype (no label): *Pustularia bistrinotata* SCHILDER & SCHILDER (1937), 152/73 (body whorl without extremities 117), dorsum regularly convex (not humped), granulate (but top almost smooth), dorsal sulcus distinct,

anterior and posterior teeth of both lips more or less crossing the margins of the shell; dorsum bleached, now whitish, with very pale yellowish dorsal specks and three distinct yellowish blotches along the dorsal line, but basal blotches are not visible.

Second shell: 142/65 (body whorl 114), still more worn, but probably identical.

The dorsal blotches of the bleached neotype are very pale so that they evidently escaped LINNAEUS' observation, and he did not mention them in the description and quoted a figure of *staphylaea* which also has an unspotted dorsum; but HANLEY (1855, p. 198) possibly noticed the dorsal spots, as he referred *cicercula* to an illustration of SOWERBY (1836) which shows the dorsally spotted *bistrinotata*. Therefore, in future *bistrinotata* should be called *cicercula*, and the granulated unspotted whitish *cicercula* of various authors should be called *lienardi* (JOUSSEAUME, 1874).

#### *Bulla ovum* (327, 369)

Lectotype (label 327): *Ovula ovum*, 732/62, not fully grown as the extremities are less developed; inside brownish orange.

Second shell: 806/59, adult, inside orange brown, outer lip very pale pinkish white.

#### *Bulla volva* (328, 370)

Holotype (no label): *Volva volva*, 570/26 (anterior beak 122, posterior beak 188 so that the body whorl is only 260), subjunior, dorsum smooth (longitudinal lines of growth excepted), but the beaks show coarse spiral lines, outer lip yet hardly thickened, but distinctly undulate, posterior funiculum of the inner lip absent; bleached.

#### *Bulla birostris* (—, 371)

There are two shells marked as *birostris* by HANLEY which differ in shape, thickness of outer lip, and color; but LINNAEUS' accurate description fits one of them only, as HANLEY (1855, p. 200) also emphasized: therefore this shell must be regarded as

Holotype (no label): *Volva brevirostris* (SCHUMACHER, 1817), 281/36, outline of the shell (but not the funiculum!) recalling figure 73 in SCHILDER (1932), outer lip thickened, rounded, basally slightly undulate, aperture much dilated in front, fossula very narrow and shallow, striated, the interior carina indistinctly reaching the posterior funiculum which consists of two faint denticles; bleached, but evidently pinkish.

The other shell seems to be *Volva longirostrata* (SOWERBY, 1828): 282/22, recalling fig. 78 in SCHILDER (1932), therefore much more slender than the holotype,

with the outer lip narrow, and the funiculum and fossula both totally absent; probably more whitish.

Therefore *Volva brevirostris* (SCHUMACHER, 1817) should be called *V. birostris* (LINNAEUS, 1767), and *V. birostris* SCHILDER (1932) should be called *V. longirostrata* (SOWERBY, 1828).

#### *Bulla spelta* (329, 372)

Lectotype (no label): *Simnia spelta*, 125/50, recalling figure 58 of SCHILDER (1932), but the interior carina is less distinct though it extends along the whole columella; whitish (bleached).

Five other specimens (82, 85, 101, 108, and 141/37) are juvenile stages of *Simnia spelta*, whitish, with the outer lip acute (not yet inflected), a distinct spiral anterior terminal ridge, an indistinct interior carina, and a posterior funiculum recalling fig. 51 of SCHILDER (1932); as LINNAEUS described the species "*marginis incrassato*" these juveniles cannot be regarded as types.

As the lectotype is a very broad specimen of *Simnia spelta*, the variety *obsoleta* (LOCARD, 1892) must be regarded as a synonym.

#### *Bulla verrucosa* (330, 373)

Holotype (no label): *Calpurnus verrucosus*, 233/60, rather narrow and humped, dorsum finely striated, with a distinct transverse carina; bleached, as the pink color of the extremities is hardly discernible and the orange rings around the terminal tubercles are pale.

#### *Bulla gibbosa* (331, 374)

Neotype (no label): *Cyphoma gibbosa*, 218/60, dorsal carina prominent, outer lip rather narrow but both lips distinctly thickened behind, no traces of teeth, fossula broad, declivous, interior slightly carinate; bleached, but the margins evidently were pinkish orange.

Three other shells (191/61, 219/57, and 230/53) are similar, but colorless; 219/57 is not fully grown as the dorsal carina is less developed.

#### *Bulla cypraea* (0, 389)

Neotype (no label): *Erosaria spurca*, 168/55, oliviform stage (protoconch and almost three whorls), outer lip acute (not inflected), posterior extremity flattened, the small spire acutely protruding from this plane; pale fulvous, the posterior plane whitish, spire rich brownish purple.

Two other oliviform shells (137 and 174) are very similar, but their spire is pale flesh color.

Such juveniles could be interpreted as other species of *Erosaria* too, but as LINNAEUS indicated them to come

from the Mediterranean Sea, they must be interpreted as *E. spurca*; even LINNAEUS stated the synonymy in 1767 (page 1180).

*Cypraea cervus* (Mantissa, p. 584)

Holotype (no label): *Macrocypraea cervus*, 1130/55 48:38, spire short (6mm long), aperture wide, fossula reduced, columella without any distinct sulcus, ribbed in front, with internal nodules in the center, and smooth behind; chestnut, white spots small (especially those on the right margin), spots never ocellated.

*Cypraea punctata* (Mantissa p. 584)

Holotype (no label): *Notadusta punctata*, 136/55 21:22, oblong-ovate, subpyriform, right side slightly margined, posterior extremity with a distinct callosity on the left, aperture slightly curved behind, outer lip declivous in front, labial teeth crossing one third of the lip, columellar teeth confined to the edge of the aperture, posterior tip of the inner lip slightly produced and slightly bent to the left, fossula narrow, rather concave, ribbed; dorsum greyish white, possibly slightly zonate with yellowish white, dorsal spots rather large and distant, lateral spots regular, but terminal spots obsolete (the left anterior spot excepted), base probably without yellow lines.

These characters prove the holotype to belong to the Malayan race called *atomaria* (GMELIN, 1791) in my previous papers.

## ADDITIONAL REMARKS

In the last drawer of Linnaeus' cowries there were many specimens belonging to species which were unknown to Linnaeus, viz. "*Cypraea*" *aurantium* GMELIN, 1791, *camelopardalis* PERRY, 1811, *chinensis* GMELIN, 1791, *cinerea* GMELIN, 1791, *diluculum* REEVE, 1845, *interrupta* GRAY, 1824, *listeri* GRAY, 1824, *miliaris* GMELIN, 1791, *pantherina* SOLANDER, 1786, *pyrum* GMELIN, 1791, *turdus* LAMARCK, 1810, *zonaria* GMELIN, 1791 as well as two species belonging to *Pusula*, viz. *quadripunctata* (GRAY, 1827) and *suffusa* (GRAY, 1827). They evidently have been added later on, as Linnaeus' publications do not contain the descriptions of them; therefore they need no discussion in this paper.

## DISCUSSION

The main question which arises from these investigations concerning the cowrie shells preserved in Linnaeus' cabinet in the Linnean Society of London are as follows:

1. Is science prepared to recognize the shells selected as

holotypes, lectotypes, or neotypes to be formal type specimens according to art. 71 to 75 of the International Rules of Zoological Nomenclature (1958)?

2. Is the type specimen or the original description decisive, if there are differences between them? In cowries these differences refer never to the mostly short diagnoses of characters themselves, but only to the quotations of previous illustrations and to the indications of habitat mostly adopted from previous writers.

If, as I suppose, the first answer would be affirmative, and the type specimens have prevalence, the following important changes in nomenclature should take place:

Former Name	New Name
a) on the specific level	
<i>Pustularia</i>	
<i>bistrinotata</i> SCHILDER & SCHILDER	<i>cicercula</i> (LINNAEUS)
<i>cicercula</i> (LINNAEUS)	<i>lienardi</i> (JOUSSEAUME)
<i>Erosaria</i>	
<i>labrolineata</i> (GASKOIN)	<i>flaveola</i> (LINNAEUS)
<i>Volva</i>	
<i>brevirostris</i> (SCHUMACHER)	<i>birostris</i> (LINNAEUS)
<i>birostris</i> (LINNAEUS)	<i>longirostrata</i> (SOWERBY)
b) on the subspecific level	
<i>Mauritia arabica</i>	
<i>dilacerata</i> SCHILDER & SCHILDER	<i>arabica</i> (LINNAEUS)
<i>arabica</i> (LINNAEUS)	<i>intermedia</i> (GRAY)
<i>Erronea onyx</i>	
<i>succincta</i> (LINNAEUS)	<i>adusta</i> (LAMARCK)
<i>Palmadusta punctata</i>	
<i>atomaria</i> (GMELIN)	<i>punctata</i> (LINNAEUS)
<i>punctata</i> (LINNAEUS)	<i>berinii</i> (DAUTZENBERG)
<i>Erosaria poraria</i>	
<i>scarabaeus</i> (BORY)	<i>poraria</i> (LINNAEUS)
<i>poraria</i> (LINNAEUS)	<i>wilhelmina</i> (KENYON)

c) on synonymic level

*Mauritia*  
*histrion* syn. *amethystea* (LINNAEUS)  
*arabica* syn. *amethystea* (LINNAEUS)

But the following change should be rejected:

*Trivia*  
*arctica* (MONTAGU) *anglica* (LINNAEUS)  
*monacha* (DA COSTA) *europaea* (LINNAEUS)

Some further changes of dubious regional "races" and of type localities are less important.

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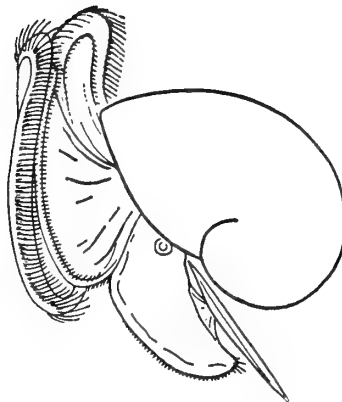
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A Study of Mitrid Radulae  
and a Tentative Generic Arrangement  
of the Family Mitridae  
(Mollusca: Gastropoda)

BY

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(47 Text figures)

DURING THE COMPILATION of the faunal monograph on Fijian Mitridae (CERNOHORSKY, 1965), some difficulty was experienced with the correct generic assignment of certain Fijian mitrids; furthermore, the taxonomic value of certain accepted genera remained obscure.

The works of THIELE (1931) and WENZ (1943) remain the only recent taxonomic treatments on the subdivision of the family, although a recent paper by COTTON (1957) does contain some proposals on the generic division of the Mitridae. The latter work, however, is restricted to genera inhabiting Australian waters, and the excessive number of genera listed (26 genera for 250 species) was based on conchological characters.

Very little work has as yet been done on the anatomy of the Mitridae, and the present tentative arrangement of the group will remain only an incomplete account in this respect. With a broadening knowledge and future research on the family, changes and revisions are to be expected.

This review is mainly concerned with living genera of Mitridae, and extinct genera have been omitted from the synonymy. It should be pointed out that the synonymy of fossil genera, i.e. those regarded as chronological congeners of recent genera, may not be complete; the comprehensive library required to achieve this end is not at the writer's disposal. Furthermore, some conclusions reached, particularly the generic relationship, must for the time being remain hypothetical; additional information and data will of course prevent a stagnancy of the present proposed arrangement.

Dr. Myra Keen, Stanford University, kindly drew my attention to the fact that Mr. Eugene Coan, Stanford

University, was presently working on a generic revision of Mitridae in preparation for the "Treatise on Invertebrate Paleontology." It was agreed between Mr. Coan and myself to present this paper as a self-contained unit of analytical conclusions based on anatomy, ecology and external morphology of mitrid mollusks. Mr. Coan's research work appears below and provides a more comprehensive taxonomic treatment of the group, with pertinent information on taxonomy and bibliography on Recent and fossil genera.

## INTRODUCTION

A generic subdivision of the family based purely on conchological characters must inevitably differ from one based on shell, radula, anatomy, ecology and distribution. Although shell characters are well defined in most cases, they are by no means clear-cut in all species of the respective genera; this is especially noticeable in such related genera as *Vexillum* and *Pusia*, and *Mitra* and *Strigatella*. Species belonging to these genera may not always be correctly assigned to the proper genus on shell morphology alone; since the radulae, however, are often fundamentally different, a generic separation can be achieved through radula examination.

Results of radula studies of mitrids may be found in the works of several authors, e.g. GRAY (1853), TROSCHEL (1868-1869), COOKE (1920), PEILE (1922, 1936, 1937), THIELE (1931), HABE (1943), BARNARD (1959), and CERNOHORSKY (1965, 1966). The English malacologists COOKE and PEILE based their subdivisions of the

family primarily on the radulae of the various mitrid groups. COOKE (*l.c.*) found the radula pattern of mitrids to fall into 12 distinct groups, and PEILE (1936) added an additional group to COOKE's subdivision. COOKE (*l.c.*) pointed out that the lateral teeth of Mitridae are of superior value in estimating the relationship of allied groups and species. This is indeed true, since the diverse pattern of the rhachidians may crop up at any time in almost any genus with the exception of *Vexillum* and *Pusia*; the pattern of the laterals, however, is peculiar only to a certain group of species or a certain genus. COOKE (*l.c.*) points out that in this respect the Mitridae fall into line with the allied genera *Fusus* BRUGUIÈRE, 1792, *Fasciolaria* LAMARCK, 1801, *Latirus* MONTFORT, 1810, and *Peristernia* MÖRCH, 1852, in all of which the laterals rather than the rhachidians supply the best evidence for classification.

It is unfortunate that the identity of the radulae in COOKE's study must often be suspect. COOKE examined and figured mostly radulae from the Gwatkin collection, and rarely if ever saw the actual shells from which these radulae were removed. In the case of well-known species the identification was most probably correct, but the far from stabilized mitrid nomenclature of the 1920's made an always correct identification impossible. PEILE (1936) and BARNARD (1959) also commented on the matter of misidentifications among the Gwatkin radulae. Speculations as to the true identity of certain radulae could have been eliminated if an illustration of the species from which the radula was removed had been cited.

## HISTORICAL

The Linnaean species of Mitridae were originally placed in the genus *Volyta* LINNAEUS, 1758, with the exception of *Pterygia scabricula* (LINNAEUS) which was assigned to *Buccinum* LINNAEUS. RÖDING (1798) established the genera *Mitra*, *Vexillum* and *Pterygia*, although the latter was probably not intended for the group of Mitridae as used at present. SWAINSON (1831) established the genera *Tiara*, *Mitrella* (= *Swainsonia* H. & A. ADAMS) and *Mitreola*. In 1840 the same author drastically reorganized the family and placed the subfamilies Volutinae and Mitrinae in the family Volutidae. The Mitrinae were divided by SWAINSON into two genera, i.e. *Mitra* and *Tiara*, which in turn were divided into 10 subgenera; the genera *Mitreola*, *Conoclix* (= *Imbricaria* SCHUMACHER, 1817) and *Mitrella* (= *Swainsonia* H. & A. ADAMS) were classed as "aberrant genera." From these 15 Swainsonian genera and subgenera, 8 have a basis in radula characters, while

one genus (*Mitreola*) based on a fossil species remains of doubtful value.

COOKE (1920) divided the Mitridae into 12 separate groups according to the diverse radula patterns, but provided only very few taxonomic units for the reception of his groups. The majority of his groups is acceptable, with the exception of group 3 (*Mitra coriacea* REEVE, 1845) and group 9 (*M. aerumnosa* MELVILL, 1888) which must be synonymized with *Mitra* s. str.

In comparison with its next allied family, the Volutidae, the mitrids remained undivided for a considerable length of time, although their radulae are as diverse as those of the volutids; consequently, the genera *Mitra* and *Vexillum* proved to be the favourite dumping ground for an array of unrelated forms. In contrast to the mitrids, the Volutidae have been subdivided to such an extent that in a recent review of the family (WEAVER, 1964) the 209 valid species are assigned to 67 genera; 62 of these have been established for living species only, and on an average the distribution is about three species per genus, while only four species remain in the Linnaean genus *Voluta*. The present tentative division of the family into 12 genera and 4 subgenera may therefore appear somewhat conservative; this arrangement, however, corresponds more or less to our present-day knowledge of the group.

## GENERAL

The Mitridae are rhachiglossate prosobranchs of the order Neogastropoda within the superfamily Volutacea. An estimated 85% of all recent species inhabit the Indo-Pacific region, 5% the Mediterranean and East Atlantic regions, while the remainder is distributed over the West Atlantic, Caribbean and Panamic regions. Members of the family prefer warm and temperate waters, and 80% of all species are tropical and subtropical in distribution. The geographical area from Mozambique to Polynesia is the richest in species, with the distributional optimum reaching its apparent saturation point in the Western Pacific arc province and declining in all four directions of the compass.

In comparison with other groups of mollusca, the Mitridae are geologically speaking a comparatively young family and most probably arose during Cretaceous times from a buccinoid ancestor; they are already well represented in Eocene deposits of Europe and the Lower Mokattam beds (Middle Eocene) of Egypt. Prior to the disappearance of the ancient Tethys sea, Mitridae spread into the West Atlantic and Indo-Pacific regions, and



during Miocene times were well established in South Africa, India, Japan, Australia and Indo-Pacific Islands. With the declining temperatures of the Late Oligocene and Early Miocene and the gradual vanishing of the tropical Tethys fauna, the mitrid genera *Cancilla* and *Vexillum* are dying out in the European region, and the

Pacific offshoots. The genus *Charitodoron* TOMLIN, discovered only in recent years, is somewhat of an enigma in the evolutionary theory of the mitrids, and certainly requires further study; it may well represent the most primitive genus of the family.

Mitrid species of the Early Tertiary are almost entirely extinct, while those of Late Tertiary resemble Recent forms from which they can be separated only infraspecifically. Pleistocene representatives, however, do not appear to differ from Recent living forms.

MATERIAL AND METHODS

Moderately large radulae (3mm to 8mm) have been dissected directly from the buccal region of the animal and cleaned from adhering muscle tissue in a 5% cold solution of sodium hydroxide. Smaller radulae (2mm to 3mm) have been removed by complete dissection of the buccal bulb region and were soaked in a 5% cold solution of NaOH for 24 hours. Very small radulae (1mm to 1.5mm) have been extracted by placing the complete animal in a 10% cold solution of NaOH for 24 hours. Direct dissection and removal of the odontophore is preferable, since potassium hydroxide or sodium hydroxide are not without effect upon chitinous material of the radula, especially in cases where the ribbon is thin and delicate. Hard to find radulae were located by adding a drop of a 1% solution of chlorazol azurine to the macerated material.

A curling of the radula at either end of the ribbon was often experienced. The radula may be successfully straightened by placing the ribbon on the glass-slide with a droplet of water and straightening the first half dozen rows at the nascent end with a needle; the cover-slide is then placed on the flattened portion of the ribbon and gently slid towards the anterior end while at the same time the ribbon is being uncurled with a fine needle from underneath and ahead of the cover slide. Care should be taken in this manipulation as otherwise the ribbon might be severed or teeth displaced.

After cleaning in fresh water, radulae were placed in 70% alcohol for 24 hours, and upon removal dehydrated with 80%, 90% and absolute alcohol. Since most mitrid radulae can be examined unstained, no staining medium has been used as this tends to oxidize in time in tropical climates. Care has been taken in not exerting pressure when placing the cover glass on the slide, since laterals may be splayed and in a different position than is the case in nature.

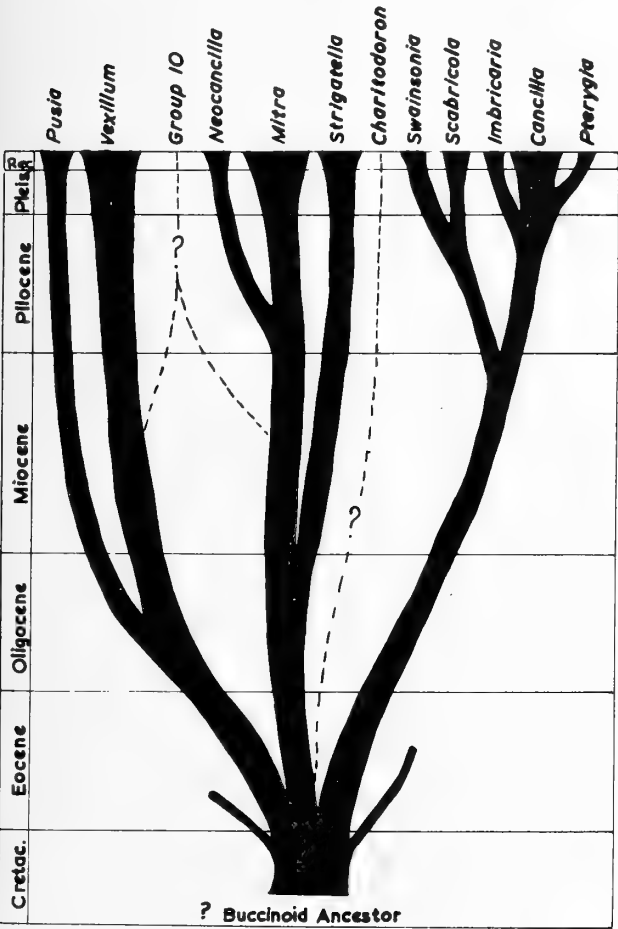


Figure 1

Hypothetical Tree of Origin of the Genera of the Mitridae

genus *Mitra* has moved toward warmer seas during Pleistocene times. The genera *Strigatella*, *Pusia* and *Scabricola* are probably later developments of the mitrid branch and may have developed during Early Miocene, while *Swainsonia*, *Imbricaria* and *Pterygia* are Recent Indo-

## VOLUTACEA

## MITRIDAE SWAINSON, 1831

The family is a fairly large one, containing about 500 Recent species. In the present account 4 subfamilies, 12 genera and 4 subgenera are considered.

**Animal:** Animal with a moderate or large foot, bluntly truncated anteriorly, pointedly rounded posteriorly; in certain sand-dwelling genera the foot extends posteriorly past the apex of the shell. Mantle thin, papillae absent; siphon moderately long or short, thick or slender, simple at distal end; eyes in the form of a simple unicoloured pupil or occasionally ringed, situated near the extremity of the broad base of the tentacles, which may be long or short; proboscis short and thick or long and slender.

**Anatomy:** The animals are gonochoristic, with the variable penis situated behind the right tentacle; it lies entirely under the mantle facing backwards. Proboscis containing a small odontophore, secured to the wall by a pair of nerve tissues. Salivary glands paired but merging in some subfamilies; a part of the hypobranchial gland is responsible for the purple secretion consisting of the chemical dibromindigotin. A poison gland which is long, slender, smooth and extendable, is present in most subfamilies with the exception of the Vexillinae; the poison gland is fawn coloured and pointed at the distal end in *Mitra clathrus* (GMELIN), and measured 19.0 mm in an animal with a shell 33 mm long. Osphradium well developed in most genera, and an oesophageal caecum ("Vorderdarm" or fore-gut gland of THIELE) is present in all families except the Vexillinae (*vide* THIELE, 1931).

**Radula:** Radula of the rhachiglossan type, consisting of various patterns in different genera but primarily of triserial construction, with only one genus (*Pterygia*) lacking laterals. Radula moderately short, ranging from 1 mm to 10 mm (3% to 35% of shell-length) and fairly narrow, i. e. from 9% to 30% in width of total ribbon length; the ribbon is variable in colour, but generally translucent white, yellow, amber or rusty-brown. The rhachidian teeth range from unicuspid to multicuspid, while the laterals are undergoing reduction and in the subfamily Vexillinae are reduced to simple "sickle-shaped" teeth. A similar diversity of the rhachidians can be observed in the Volutidae, where characters vary from the multicuspid rhachidian of *Voluta* LINNAEUS, tricuspid rhachidian of *Aulica* GRAY, 1847, and *Cymbiola* SWAINSON, 1831, to the unicuspid rhachidian of *Amoria* GRAY, 1855. In the Mitridae there is a definite correlation between the length and number of teeth of the ribbon as compared to shell-length.

**Shell:** Shell from 5 mm to 170 mm in size, variable in shape, but generally fusiform, turreted, pyriform ovate or cylindrical. Whorls number from 6 to 13, nuclear whorls from 1 to  $3\frac{1}{2}$  and are generally glassy and smooth. Shell either smooth or sculptured with axial plicae, transverse ridges, grooves, pits or nodules. Columella usually calloused and with from 2 to 9 oblique plicae; in the genus *Charitodoron* TOMLIN, 1932, the columella is smooth. Aperture broad or narrow, outer lip thick or thin, smooth or nodulose; labrum smooth or lirate, siphonal canal short and truncated or prominently produced, periostracum present, operculum wanting.

**Feeding Habits:** Primarily carnivorous, although radular evidence suggests a divergence of feeding habits. The construction of the radula of sand-dwelling mitrids would make the radula particularly suitable for a tearing and shredding technique of feeding; more often than not, laterals are missing in the front rows of the ribbon, and cusps of rhachidians are broken off at their bases. In coral-dwelling *Strigatella* and some *Mitra*, the rhachidians and laterals are both worn down in the first dozen rows of the ribbon. It would therefore appear that coral-dwelling species are sweeping and grazing over detritus layers of the coral substratum in search of microorganisms for food.

**Habitat:** Mitridae are generally found buried in clean or muddy sand of wide lagoons or in sand-pools of coral reefs; some genera appear to be confined to cracks and crevices of coral reefs of the intertidal zone or inhabit the underside of coral and basalt boulders. The majority of species is confined to the shallow waters of the intertidal zone, although some have been dredged from a depth of 940 fathoms.

**Geographical Distribution:** In warm and temperate seas of all major geographical provinces.

**Geological Distribution:** From the Eocene to Recent.

**Economic Importance:** Large species of Mitridae were employed in the manufacture of native implements by Pacific islanders during the last century and prior to that as hand-tools and net-weights by various Pacific communities; otherwise there seems to be little commercial use for this family of mollusks.

## Mitrinae SWAINSON, 1831

(Mitrianae, Mitranae, Mitriana SWAINSON, 1831 — emended to Mitrinae SWAINSON, 1840)

This subfamily includes one of the oldest surviving genera and its offshoots and is divided into 5 genera and one subgenus.

The radula is triserial, rhachidians are small and variable in shape, with from 3 to 12 cusps, laterals variable

in form and with 10 to 45 cusps; extendable poison gland present in members of this subfamily. Eggs laid in vase-shaped egg-capsules, 15 to 40 scattered over the substratum; each capsule contains from 300 to 500 white, cream-coloured or translucent-yellow eggs.

*Mitra* RÖDING, 1798

*Mitra* RÖDING, 1798, Mus. Bolten., p. 135 – Type species by subsequent designation (WINCKWORTH, 1945) *Voluta episcopalis* LINNAEUS, 1758 = *Mitra mitra* (LINNAEUS).

Shells 10 mm to 170 mm in size, generally ovate, elongate-ovate or fusiform, smooth or spirally grooved, ridged or pitted, aperture variable, outer lip smooth or crenulate, labrum smooth, columella with 3 to 7 plicae, siphonal canal short or moderately long; shell generally covered with a moderately thick epidermis.

Radula with three teeth per row, rhachidian moderately small, quadrate, rectangular, trapezoidal or triangular, concave, with 3 to 12 cusps. Laterals ranging from two to four times the width of rhachidians, short and broad, comb-like, with a convexity at the base and with from 10 to 45 prominent cusps distributed over the entire width of the plate. The ribbon has a width of 16% to 30% of total ribbon-length, and from 9% to 12% of total shell-length; the number of rows per 1 mm of ribbon length varies from 15 to 33, and from 16 to 30 per 10 mm of shell length.

Habitat is in sand or sand substratum under coral rocks or in cracks and crevices of coral rocks, from shallow to deeper water.

Geologic distribution is from Eocene to Recent. Since Pliocene times the genus occurs only in the Indo-Pacific, Panamic, Caribbean, Atlantic and Mediterranean regions.

*Mitra mitra* (LINNAEUS, 1758), CERNOHORSKY, 1965, The Veliger 8 (2): 91; plt. 13, fig. 1.

Radula of specimen from the Fiji Islands: Radular ribbon white in colour, 5.1 mm long and 0.8 mm wide in shell 50 mm in length; fully-formed rows number 76 (+ 5 nascentes), with the front three to four rows of teeth equally worn. Rhachidians with five prominent cusps, central cusp more massive and longer than side-cusps. Laterals  $2\frac{1}{2}$  times as broad as rhachidians, comb-like and with 13 to 15 cusps distributed over the entire width of the lateral plate; the last three to four cusps often appear as small denticles.

Proboscis extremely long in comparison to shell size, and was found to measure 37 mm in a 50 mm long specimen.

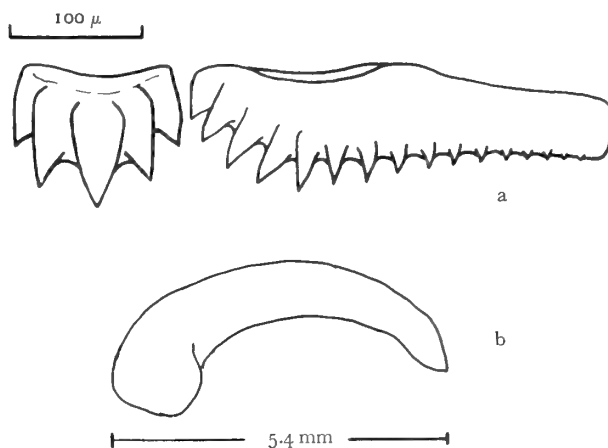


Figure 2

a: Half-Row of Radular Teeth of *Mitra mitra* (LINNAEUS)  
b: Lateral View of Penis

*Mitra idae* MELVILL, 1893; SHIKAMA, 1963, plt. 74, fig. 16.

Radula of specimen from Point Conception, California: Radular ribbon amber in colour, 6.8 mm long and 1.5 mm wide in shell 54 mm in length; fully-formed rows number 98 (+ 4 nascentes), rhachidians of the front 13 to 14 rows of teeth badly worn; laterals equally worn in front



Figure 3

Half-Row of Radular Teeth of *Mitra idae* MELVILL

16 rows, with the four large cusps facing the rhachidians either worn down or broken off. Rhachidians with 6 prominent cusps, two central cusps about equal-sized. Laterals four times the width of rhachidians, with 32 cusps distributed over the entire width of the plate, last 6 cusps appearing as weak denticles.

The radula of *Mitra idae*, the type of *Atrimitra* DALL, 1918, resembles that of *M. stictica* (LINK, 1807). *Atrimitra* DALL should be placed in the synonymy of *Mitra* s. str.

*Mitra cardinalis* (GMELIN, 1791); CERNOHORSKY, 1965, The Veliger 8 (2): 82; plt. 13, fig. 2.

Radula of specimen from Fiji: Radular ribbon white, 4.2 mm long and 0.94 mm wide in shell 41 mm long; fully



Figure 4

Half-Row of Radular Teeth of *Mitra cardinalis* (Gmelin)

formed rows number 58 (+ 4 nascentes) and the laterals of the front 3 to 4 rows have some cusps broken off. Rhachidians with 7 prominent deeply-rooted cusps; side-cusps rather small and almost obsolete in some rows of the same ribbon. Laterals about  $2\frac{1}{4}$  times the width of rhachidians, with 16 to 17 cusps distributed over the entire width of the lateral plate.

*Mitra eremitarum* RÖDING, 1798; CERNOHORSKY, 1965, The Veliger 8 (2): 87; plt. 13, fig. 3.

Radula of specimen from Fiji: Radular ribbon amber in colour, 3.8 mm long and 0.56 mm wide in shell 49 mm in length; fully-formed rows number 68 (+ 1 nascent) and the front 12 to 14 rows of teeth are badly worn.

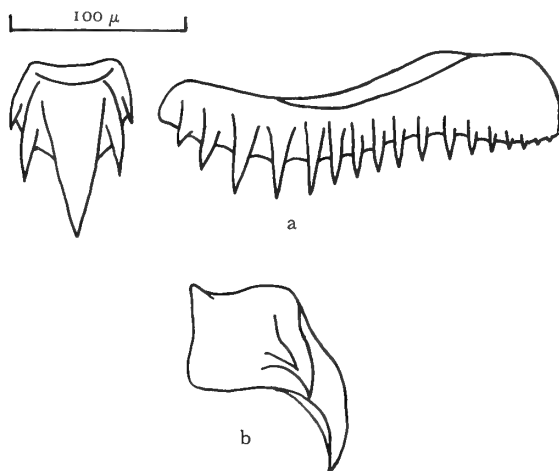


Figure 5

a: Half-Row of Radular Teeth of *Mitra eremitarum* RÖDING  
b: Lateral View of Rhachidian

Rhachidians dark amber in colour, with 5 cusps, central cusp large and massive, side-cusps smaller and slender. Laterals greyish-white, about 3 times the width of rhachidians with 16 to 17 cusps distributed over the entire width of the lateral plate.

The proboscis is very long, measuring 37 mm in a shell 49 mm in length. COOKE's figure of the radula of *Mitra adusta* LAMARCK (1920, fig. 1) is appreciably different and most probably originated from a different species.

*Mitra fraga* QUOY & GAIMARD, 1833; CERNOHORSKY, 1965, The Veliger 8 (2): 89; plt. 16, fig. 42.

Radula of specimen from Fiji: Radular ribbon translucent-white, 1.1 mm long and 0.25 mm wide in shell 12 mm in length; fully formed rows number 34 (+ 3 nascentes) and the front two to three rows of teeth are badly worn. Rhachidians with 7 fairly prominent cusps, central

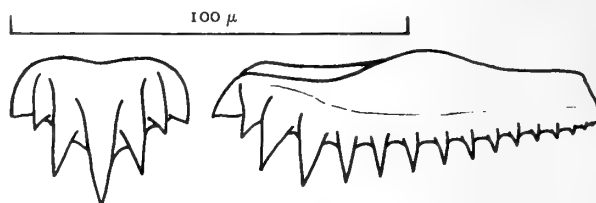


Figure 6

Half-Row of Radular Teeth of *Mitra fraga* QUOY & GAIMARD

cusp the longest. Laterals about 2 to  $2\frac{1}{2}$  times the width of rhachidians, with 13 to 15 cusps distributed over the entire width of the plate; cusps diminish in size toward the end where they appear as small denticles.

*Mitra stictica* (LINK, 1807); CERNOHORSKY, 1965, The Veliger 8 (2): 98; plt. 14, fig. 15.

Radula of specimen from Fiji: Radular ribbon light brown in colour (nascentes end white), 6.1 mm long and 1.9 mm wide in shell 66 mm in length; fully formed rows



Figure 7

Half-Row of Radular Teeth of *Mitra stictica* (LINK)

number 77 (+ 4 nascentes), and the front 10 rows are badly worn, especially the rhachidians. Rhachidians with 6 prominent cusps, with the two central cusps equal in size. Laterals about  $3\frac{1}{2}$  times the width of rhachidians, with 26 to 30 cusps which decrease in size towards the

end and are distributed along the entire width of the plate.

Proboscis flesh-coloured, 55 mm long in shell 66 mm in length.

The genera *Tiarella* SWAINSON, 1840 and *Papalaria* DALL, 1915, established for the group of species comprising *Mitra papalis* (LINNAEUS), *M. stictica* (LINK), *M. cardinalis* (GMELIN), etc., should be placed in the synonymy of *Mitra* s. str.

*Mitra ferruginea* LAMARCK, 1811; CERNOHORSKY, 1965, The Veliger 8 (2): 88; plt. 13, figs. 7, 7 a.

Specimen from Fiji: Radular ribbon translucent white, 3.1 mm long and 0.44 mm wide in shell 48 mm in length; fully formed rows number 88 (+ 3 nascentes), and wear



Figure 8

Half-Row of Radular Teeth of *Mitra ferruginea* LAMARCK

is discernible on the front rows of the ribbon. Rhachidians with 5 massive cusps, central cusps the longest. Laterals with 11 to 13 cusps, last 2 to 3 cusps appearing as minute denticles.

COOKE (1920) placed this species in section 3 of group 1; the rhachidian depicted in COOKE's figure (fig. 3) shows a rhachidian with 6 equal-sized slender cusps and hardly resembles the rhachidian of *Mitra ferruginea* examined in this study.

*Mitra cucumerina* LAMARCK, 1811; CERNOHORSKY, 1965, The Veliger 8 (2): 87; plt. 17, figs. 50, 50 a.

Specimen from Fiji: Radular ribbon translucent-white in colour, 2.5 mm long and 0.45 mm wide in shell 25 mm in length; fully formed rows number 37 (+ 3 nascentes) and front rows of teeth hardly show any wear at all. Rhachidians with 3 prominent deeply-rooted cusps, central cusps slightly larger. Laterals about  $1\frac{1}{2}$  times the width of the rhachidians with about 11 cusps; the first cusp is beak shaped and facing the rhachidian, while the ultimate  $\frac{1}{2}$  of the plate is bare.



Figure 9

Half-Row of Radular Teeth of *Mitra cucumerina* LAMARCK

The radula of *Mitra cucumerina* is quite different from that of *M. chrysalis* REEVE, although the shells of the two species are somewhat similar. In *M. chrysalis* the rhachidians have 8 to 10 long and slender cusps while the cusps on the laterals are more numerous.

*Mitra auriculoides* REEVE, 1845; CERNOHORSKY, The Veliger 8 (2): 109; plt. 18, fig. 61.

Specimen from Fiji: Radular ribbon translucent-white, 1.4 mm long and 0.21 mm wide in shell 15 mm in length; fully formed rows number 57 (+ 3 nascentes), and the front 2 to 3 rows are worn. Rhachidians with 8 moderately long cusps, the 4 central cusps about equal in length.

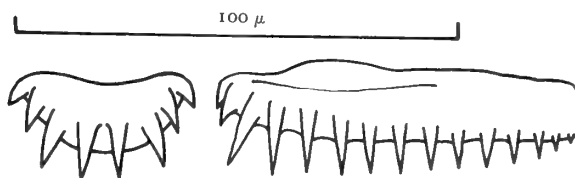


Figure 10

Half-Row of Radular Teeth of *Mitra auriculoides* REEVE

Laterals twice the width of the rhachidians with 13 to 15 cusps distributed over the entire width of the plate, gradually decreasing in size.

This species is almost always assigned to the genus *Strigatella* SWAINSON; however, the radula proves it to be a *Mitra*.

*Mitra ostergaardi* PILSBRY, 1921; J. CATE, 1962, The Veliger 4 (3): 143; plt. 33, fig. 3; plt. 35, fig. c.

Specimen from Kailua Bay, Oahu, Hawaii: Radular ribbon translucent-white, 3.2 mm long and 0.62 mm wide in shell 28 mm in length; fully formed rows number 64



Figure 11

Half-Row of Radular Teeth of *Mitra ostergaardi* PILSBRY

(+ 3 nascentes) and no appreciable wear is discernible on the front rows of teeth. Rhachidians with 8 to 9 moderately slender cusps. Laterals about twice as broad as rhachidians, with 14 to 16 slender cusps which are distributed over the entire width of the lateral plate.

*Mitra nigra* (GMELIN, 1791); ALLAN, 1959, Austral. shells, plt. 26, fig. 17 (as *Vicimitra contermina* IREDALE).

Specimen from Redhead, Bendalong, N. S. W., Australia: Radular ribbon amber in colour, 5.1 mm long and 1.2 mm wide in shell 44.0 mm long; fully formed rows number 82 (+ 2 nascentes) and front rows of teeth show considerable wear. Rhachidians with 9 deeply rooted

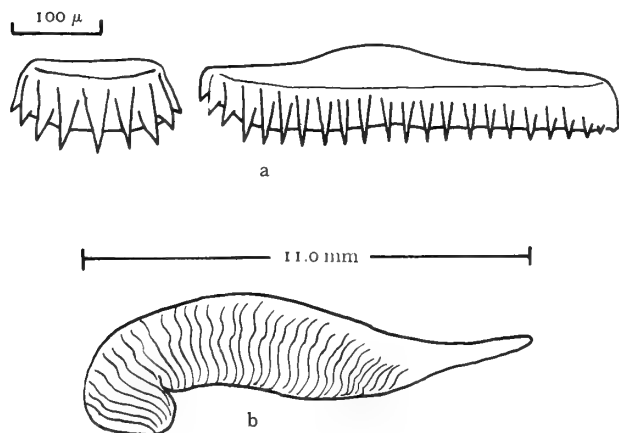


Figure 12

a: Half-Row of Radular Teeth of *Mitra nigra* (GMELIN)  
b: Lateral View of Penis

cusps, with the 3 central cusps being equal in size. Laterals about twice the width of rhachidians with 22 to 23 long and slender cusps, which are distributed along the entire width of the plate.

The proboscis measured 34 mm and the penis 11 mm, both in extended position.

*Mitra glabra* SWAINSON, 1821; ALLAN, 1959, plt. 26, fig. 18 (also REEVE, 1844, pl. 6, sp. 43).

Specimen from Redhead, Bendalong, N. S. W., Australia: Radular ribbon amber in colour, 6.1 mm long and 2.0 mm wide in shell 65 mm in length; fully formed rows number 92 (+ 3 nascentes), and some wear is visible on

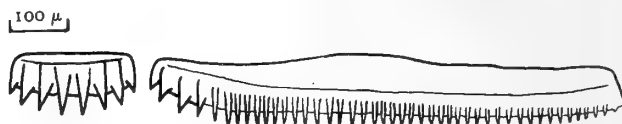


Figure 13

Half-Row of Radular Teeth of *Mitra glabra* SWAINSON

the front rows of teeth. Rhachidians with 8 to 10 deeply rooted cusps. Laterals about 4 times the width of rhachidians and with 42 to 45 very slender cusps which are distributed over the entire width of the plate.

This and the preceding species are almost always assigned to the genus *Vicimitra* IREDALE, 1929, by Australian malacologists; they should be reassigned to *Mitra* s. str.

*Mitra variabilis* REEVE, 1844; CERNOHORSKY, 1965, The Veliger 8 (2): 100; p't. 14, fig. 16.

Specimen from North-West Island, Queensland, Australia: Radular ribbon translucent white, 2.7 mm long and 0.5 mm wide in shell 32 mm in length; fully formed



Figure 14

Half-Row of Radular Teeth of *Mitra variabilis* REEVE

rows number 124 (+ 7 nascentes) and no appreciable wear was evident on the front rows of the ribbon. Rhachidians wide and short with 11 moderately long cusps. Laterals about twice the width of rhachidians with 24 to 26 slender cusps which are distributed along the entire width of the plate.

*Mitra hirasei* (PILSBRY, 1904); SHIKAMA, 1963, Shells world ill. col., plt. 74, fig. 2.

Specimen from Kiushio Island, Japan: Radular ribbon translucent white, ultimate 15 rows (nascentes excluded)

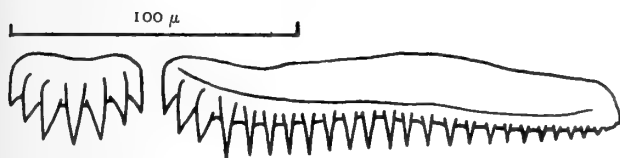


Figure 15

Half-Row of Radular Teeth of *Mitra hirasei* (PILSBRY)

orange-brown in colour, 1.3 mm long and 0.38 mm wide in shell 27 mm in length; ribbon consisting of 88 rows (+ 5 nascentes), and no appreciable wear is evident on the front rows of teeth. Rhachidians with 7 deeply rooted cusps; laterals about 3 times the width of rhachidians, with 23 to 25 moderately slender cusps which are distributed along the entire width of the plate.

This species is generally assigned to the genus *Scabricola* SWAINSON, and should be removed to *Mitra* s. str.

(*Dibaphus*) PHILIPPI, 1847

*Dibaphus* PHILIPPI, 1847, Arch. Wieg., p. 61, plt. 3, figs. 1 - 3. - Type species by monotypy *Conus edentulus* REEVE, 1844, ex SWAINSON MS, = *Mitra* (*Dibaphus*) *edentula* (REEVE).

The shells of this subgenus are generally 25 mm to 45 mm in length, cylindrical and cone-shaped, spire short, aperture long and narrow, columella with several plicae anterior of which appears to be the continuation of the spiral ridges on the body whorl; sculpture consists of small and angulate transverse grooves or ridges, interstices cancellate with axial striae.

The radula is similar to that of *Mitra* s. str., but not sufficiently different to merit generic rank. For figure of radula see COOKE, (1920, p. 409, fig. 4).

The species of the subgenus inhabit the underside of dead coral boulders on reef flats.



Figure 16

Half-Row of Radular Teeth of  
*Mitra* (*Dibaphus*) *edentulus* (REEVE)

[after COOKE, 1920, text figure 4 - no magnification]

Members of the subgenus inhabit the Indo-Pacific region and developed possibly in Recent times. The subgenus includes only a handful of species, which appear to be confined to the Indo-Pacific region.

*Strigatella* SWAINSON, 1840.

*Strigatella* SWAINSON, 1840; Treat. Malac., 127: 319. - Type species by subsequent designation (GRAY, 1847) *Mitra zebra* LAMARCK, 1811 = *Strigatella paupercula* (LINNAEUS, 1758).

Shells small or moderate in size, ovate or elongate-ovate, heavy and solid; sutures plain or coronate, whorls smooth or sculptured with striae, granules or pits; aperture narrow, outer lip thick, smooth or crenulate, generally with a prominent callus on outer lip; labrum smooth, columella with 3 to 5 plicae, anterior canal short; shell with periostracum.

The animal has generally a light-coloured sole of the foot, while the dorsum of the foot is light or dark brown. Foot, siphon, tentacles and eyes are smaller than is the case in Vexillinae.

The rhachidians are variable in pattern and similar to those of *Mitra* s. str.; in the type species the two central cusps are equal in size. Laterals are generally 2 to 3 times as broad as the rhachidians, cleaver-shaped, concavely depressed at the beginning, and with the last quarter or one-third of the lateral plate always bare of teeth. The width of the ribbon in relation to total ribbon-length varies from 9% to 20%, and from 7% to 21% in relation to total shell-length. There are about 20 to 45 rows of teeth per 1 mm of ribbon, and 25 to 50 rows per 10 mm of shell-length.

Members of the genus generally inhabit cracks and crevices of coral reefs and the underside of coral rocks in the intertidal zone.

The genus is distributed over the Indo-Pacific, Panamic, Caribbean and Atlantic regions. The genus probably developed during the Miocene.

The radula of *Strigatella* is similar in pattern to *Mitra* s. str., but differs in that the inner part of the laterals is arched and concavely depressed, while the outer part of the plate is straight; the teeth become small denticles towards the outer half of the plate, and become obsolete or absent on the ultimate third or quarter of the plate.

*Mitreola monodonta* (LAMARCK, 1803), the type species of *Mitreola* SWAINSON, 1832, is rather similar to members of the Recent genus *Strigatella*. The mammillate protoconch and heavily calloused columella of *M. monodonta* should provide the necessary excuse to separate the fossil genus *Mitreola* from the Recent *Strigatella*; genera

based on fossil type-species are after all malacologically undesirable for living groups of species.

*Strigatella paupercula* (LINNAEUS, 1758); CERNOHORSKY, 1965, *The Veliger* 8 (2): 112; plt. 17, fig. 59.

Specimen from Fiji: Radular ribbon translucent-white, 3.6 mm long and 0.52 mm wide in shell 17 mm in length; fully formed rows number 82 (+ 3 nascentes), and the front 10 rows of teeth are badly worn and mutilated.



Figure 17

Half-Row of Radular Teeth of *Strigatella paupercula* (LINNAEUS)

Rhachidians with 6 main cusps and 2 small accessory denticles which are obsolete in some rows on the same ribbon. Laterals about  $2\frac{1}{4}$  times the width of the rhachidians with 8 to 9 fairly strong cusps and 3 to 4 small denticles; the ultimate third of the plate is bare.

*Strigatella retusa* (LAMARCK, 1811); CERNOHORSKY, 1965, *The Veliger* 8 (2): 113; plt. 18, fig. 64.

Specimen from Fiji: Radular ribbon translucent-white, 2.2 mm long and 0.2 mm wide in shell 30 mm in length; fully formed rows number 102 (+ 4 nascentes). Rhachidians with 8 moderately long cusps, 2 central cusps

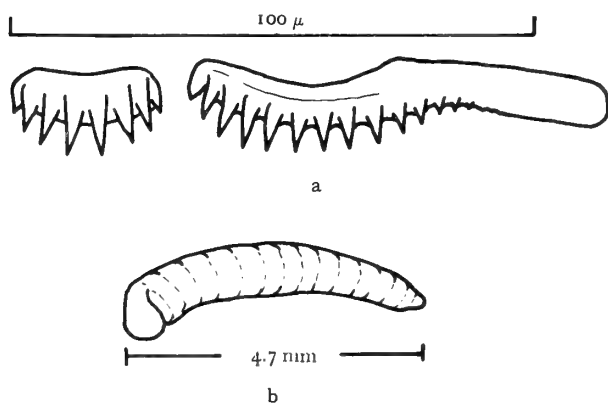


Figure 18

a: Half-Row of Radular Teeth of *Strigatella retusa* (LAMARCK)  
b: Lateral View of Penis

equal in length. Laterals  $2\frac{1}{2}$  times the width of rhachidians with 13 to 14 cusps; the last 3 to 5 cusps appear as small denticles only.

Proboscis creamy-yellow, slender at distal end, 19.0 mm in length after preservation. One specimen examined had only 49 rows of teeth in a ribbon 1.2 mm long.

*Strigatella ticaonica* (REEVE, 1844); CERNOHORSKY, 1965, *The Veliger* 8 (2): 99; plt. 14, fig. 14.

Specimen from Fiji: Radular ribbon light amber in colour, 2.9 mm long and 0.47 mm wide in specimen 23.0 mm in length; fully formed rows number 88 (+ 4 nascentes) and the rhachidians in the first two front rows have the cusps worn away. Rhachidians are roughly rectangular and equipped with 7 prominent deeply rooted cusps; the side-cusps become very small in some rows of

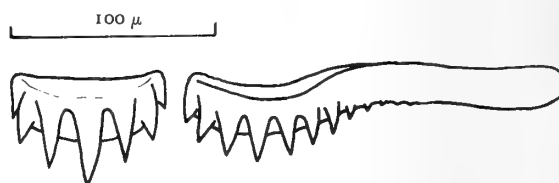


Figure 19

Half-Row of Radular Teeth of *Strigatella ticaonica* (REEVE)

the same ribbon. Laterals about  $2\frac{1}{2}$  times the width of rhachidians, concavely depressed towards centre of ribbon, and with 10 to 12 strong cusps; the last 3 to 4 cusps usually appear as small denticles, and the ultimate third of the plate is bare.

This species is generally placed in the genus *Mitra*, from which it should be removed and assigned to *Strigatella*.

#### *Neocancilla* CERNOHORSKY, gen. nov.

*Neocancilla papilio* (LINK, 1807) hereby designated as type species.

Type species: *Voluta papilio* LINK, 1807.

**Shell:** Shell moderate in size, fusiform and fairly solid, whorls convex, sculptured with transverse ridges and axial striae, giving the shell a scabrous appearance. Aperture moderately narrow, labrum smooth, outer lip thickened, crimped or obsoletely crenulate, columella plicate, siphonal canal produced.

**Animal:** Foot moderately large, varicoloured; eyes, proboscis and siphon moderately well developed.

**Radula:** Radular ribbon about 10% in width in relation



to total ribbon length, and 13% in width in relation to shell length; about 20 rows of teeth are present per 1 mm of ribbon and 23 such rows per 10 mm of shell-length. Rhachidians bicuspid, the two cusps equal in size, massive, generally flanked by one or two small denticles; laterals about  $1\frac{1}{2}$  times the width of rhachidians, somewhat degenerate in appearance, with 5 to 7 cusps and 2 to 3 small denticles.

**Habitat:** In sand only, in shallow and deeper water.

**Geographical Distribution:** Indo-Pacific, ? Caribbean region.

**Age:** Recent.

**Discussion:** The radula pattern of this group of species differs widely from other groups and is thus separated as a new genus. COOKE (1920) placed shells with a similar radula pattern in his group No. 7 but did not provide a taxonomic name for it.

*Neocancilla papilio* (LINK, 1807); CERNOHORSKY, 1965, The Veliger 8 (2): 93; plt. 14, fig. 22.

Specimen from Fiji: Rhachidians of radular ribbon rusty-brown, laterals thin and greyish-white, ribbon 3.9 mm long and 0.42 mm wide in shell 33.0 mm in length; fully formed rows number 52 (+ 14 nascentes) and only

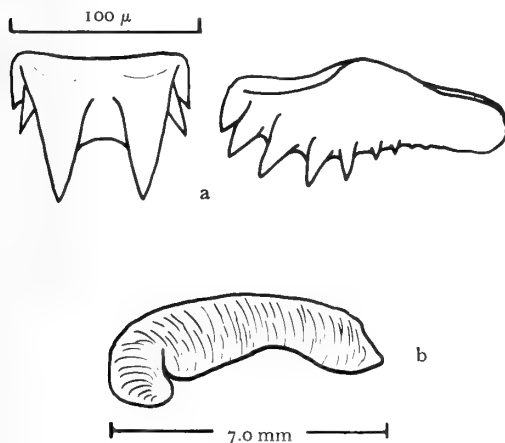


Figure 20

a: Half-Row of Radular Teeth of *Neocancilla papilio* (LINK)  
b: Lateral View of Penis

the first 2 to 3 front rows of teeth are slightly worn. Rhachidians about rectangular in shape, with 2 long and massive cusps and a pair of small overlapping side cusps on either side. Laterals  $1\frac{1}{2}$  times the width of rhachidians, with about 8 cusps, last 2 to 3 cusps generally very small. Proboscis measured 10 mm after preservation.

*Neocancilla langfordiana* (J. CATE, 1962), The Veliger 5 (2): 80-83; pls. 10, 11.

Specimen from Waianae, Oahu, Hawaii: Radular ribbon consisting of rusty-brown rhachidians and thin whitish laterals; ribbon 2.8 mm long and 0.34 mm wide in

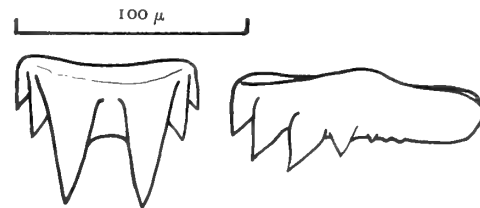


Figure 21

Half-Row of Radular Teeth of *Neocancilla langfordiana* (J. CATE)

shell 25.0 mm in length; fully formed rows number 38 (+ 8 nascentes) and the front rows of teeth displayed a negligible amount of wear. The pattern of rhachidians and laterals is very similar to that of *Neocancilla papilio* from the Fiji Islands, and the radulae also agree in many other aspects. The shells of the two species are rather similar, and both may prove to be conspecific.

*Neocancilla clathrus* (GMELIN, 1791); CERNOHORSKY, 1965, The Veliger 8 (2): 103; plt. 14, fig. 25.

Specimen from Fiji: Radular ribbon amber in colour, rhachidians rusty-brown, end of laterals thin and white, ribbon 4.3 mm long and 0.4 mm wide in shell 32.0 mm in length; fully formed rows number 77 (+ 8 nascentes),

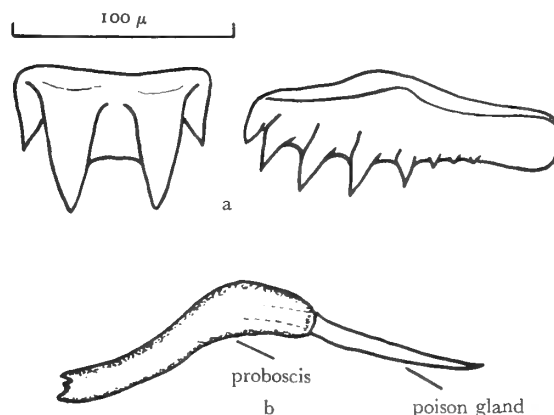


Figure 22

a: Half-Row of Radular Teeth of *Neocancilla clathrus* (GMELIN)  
b: Proboscis with Poison Gland in Extended Position

the front 3 rows of teeth being worn. Rhachidians roughly rectangular in shape, equipped with 2 long and massive cusps and 2 shorter solid side-cusps. Laterals  $1\frac{1}{2}$  times the width of rhachidians, furnished with 8 cusps; the ultimate 3 cusps are very small and appear as denticles throughout all rows of the ribbon.

The proboscis is orange-brown flecked with cream, and measured 15 mm after preservation.

*Neocancilla emersoni* (PILSBRY, 1921); J. CATE, 1962, *The Veliger* 4 (3): plt. 34, fig. 2, and plt. 35, fig. d.

Specimen from Kailua Bay, Oahu, Hawaii: Radular ribbon same colour as that of *Neocancilla clathrus*, 1.7 mm long and 0.22 mm wide in shell 15.0 mm in length; fully formed rows number 62 (+ 4 nascentes), front rows somewhat worn and laterals fractured. Rhachidians with

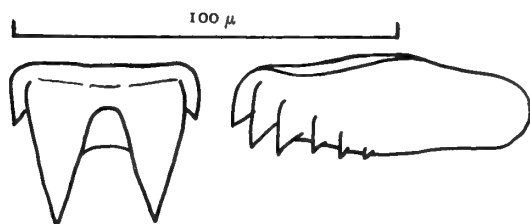


Figure 23

Half-Row of Radular Teeth of *Neocancilla emersoni* (PILSBRY)

2 massive cusps which are flanked by a small accessory cusp. Laterals about  $1\frac{1}{2}$  times the width of rhachidians, with 5 to 6 moderately small cusps, ultimate third of lateral plate bare.

The radula does not differ from that of *Neocancilla clathrus*, and the shells are similar too. I should not hesitate to place this species in the synonymy of *N. clathrus* (GMELIN).

#### *Charitodoron* TOMLIN, 1932.

*Charitodoron* TOMLIN, 1932, *Ann. South Afr. Mus.*, 30: 167. – Type species by original designation *Charitodoron euphrosyne* TOMLIN, 1932 (Natal).

**Shell:** Shell fusiform and fragile, aperture shorter than spire, sculpture consisting of spiral grooves or striae, axial ribs on early whorls, columella straight and lacking plicae, labral wall smooth, periostracum thin, operculum absent. **Animal:** Black or very dark brown, with short tentacles and no eyes (*vide* BARNARD, 1960).

**Radula:** Similar in pattern to *Mitra* s. str., with 60 to 65

rows, rhachidians with 5 main cusps and somewhat obsolete side-cusps; laterals about 2.6 times the width of rhachidians, with 10 prominent cusps distributed almost along the entire width of the plate.

**Habitat:** From 300 to 700 fathoms.

**Geographical Distribution:** Endemic to the South African region (Natal - East London).

**Age:** ? Recent.



Figure 24

Half-Row of Radular Teeth of *Charitodoron bathybius* (BARNARD)  
[after BARNARD, 1959, figure 11 c – no magnification]

**Discussion:** TOMLIN (1932) established the genus *Charitodoron* for three South African deep water species and assigned the genus to the family Buccinidae on conchological grounds. BARNARD (1959) figured the radula of *Mitra (Dibaphus) bathybius* BARNARD, 1959, and commented on the great resemblance of his new species to the shells of *Charitodoron*. BARNARD (1960) was successful in obtaining specimens of *C. pasithea* TOMLIN, 1943, and *C. thalia* TOMLIN, 1932; an examination revealed the radula to be of the same pattern as *C. bathybius* (BARNARD), with 60 to 65 rows of teeth and a rhachidian with 6 cusps (i.e. no median cusp as in *C. bathybius*). The holotype of *Charitodoron*, however, did not contain an animal.

Although the radula is of the *Mitra* pattern, morphological characters of the shells of *Charitodoron* are unlike those of any other member of the Mitridae; the columellar plaits, a characteristic represented in all mitrid genera, are lacking in the South African genus. However, some volutid genera, i.e. *Fusivoluta* MARTENS, 1902, and *Neptuneopsis* SOWERBY, 1898, from East and South African waters equally lack columellar plaits.

The lack of columellar plicae, absence of eyes in the animal (?), benthic range and geographical distribution, favour a generic separation of this group of shells. *Charitodoron* has been tentatively retained in the Mitridae mainly on radula evidence supplied by BARNARD (1959, 1960). The genus includes the species *C. euphrosyne* TOMLIN, 1932, *C. agulhasensis* [(THIELE, 1925) – syn. *C. aglaia* TOMLIN, 1932], *C. thalia* TOMLIN, 1932, *C. pasithea* TOMLIN, 1943, and *C. bathybius* (BARNARD, 1959); the last two mentioned species appear to be synonyms of *C. thalia* TOMLIN.

Genus ? (Group 10 of COOKE, 1920 and PEILE, 1936).

Mention must be made here of a group of species which possesses a radula consisting of rhachidians similar to those of *Vexillum*, but with numerous smaller denticles, and laterals similar to those of *Mitra* s. str. COOKE (1920, fig. 16) illustrated this type of radula under his group 10, and credited the radula to the species "*Mitra scabriuscula* L." PEILE (1936) points out that COOKE's identification of *M. scabriuscula* L. was an error and that "L." should presumably be "LAMARCK." The radula of *Pterygia scabricula* (LINNAEUS) differs greatly from the radula figured by COOKE (*l.c.*), and LAMARCK's "*M. scabriuscula*" is the species *Neocancilla papilio* (LINK), with a radula also differing from that illustrated by COOKE. It is quite possible that COOKE's species was *Mitra granatina*



Figure 25

Half-Row of Radular Teeth of *Mitra* Species  
[after COOKE, 1920, text figure 16 – no magnification]

Half-Row of Radular Teeth of *Mitra* Species  
[after PEILE, 1936, figure 9 – x 300]

Figure 26

LAMARCK, 1811, which is often found listed in literature as *Mitra scabriuscula* LAMARCK.

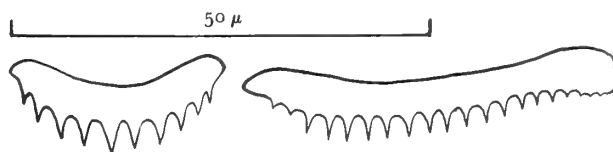
A radula similar to that figured by COOKE was described and figured by PEILE (1936, fig. 9) under the name *Cancilla circula* KIENER. This radula greatly resembles the radula of *Mitra filaris* (LINNAEUS) figured here, except that the cusps of the rhachidians in PEILE's specimens are more numerous.

*Mitra filaris* (LINNAEUS, 1771); CERNOHORSKY, 1965, The Veliger 8 (2): 104; plt. 15, fig. 33.

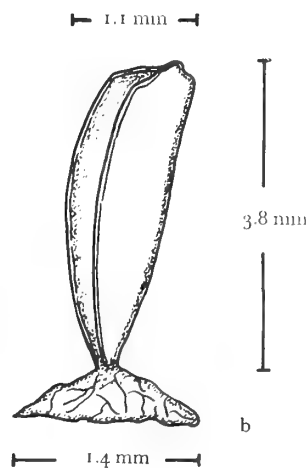
Specimen from Le Goulet, Mauritius: Radular ribbon very thin, fragile and short, translucent white in colour, 0.9 mm long and 0.12 mm wide in shell 30 mm in length; fully formed rows number 73 (+ 2 nascentes) and no appreciable wear is evident in the front rows of the ribbon apart from some missing cusps. Rhachidians concavely depressed and with 10 small and weak cusps. Laterals about  $1\frac{3}{4}$  times the width of rhachidians with 15 to 20 shallowly-rooted teeth which extend over the entire width of the plate and are very small or almost obsolete at both ends of the plate.

The above specimen was found on an egg-mass consisting of a cluster of 85 to 90 tightly packed brownish egg-capsules secured to a piece of seaweed. Capsules were on the average 3.5 to 4 mm in height, 1.0 to 1.2 mm in width and contained from 130 to 150 creamy-coloured undivided spherical eggs which measured from  $110\mu$  to  $180\mu$  in diameter; the whole egg-mass would therefore contain between 11000 and 13000 eggs.

**Discussion:** In view of the distinct radula pattern and other peculiarities of the radula, PEILE's remarks (1936)



a



b

Figure 27

a: Half-Row of Radular Teeth of *Mitra filaris* (LINNAEUS)  
b: Egg-Capsule of *Mitra filaris* (LINNAEUS)

that this group of shells is deserving of generic rank must be supported. No taxonomic unit name, however, can be applied to this group at this stage, as the radula of *Cancilla isabella* SWAINSON, the type species of *Cancilla*, is unknown. Should this species have a radula similar to that of group 10, then the group of shells comprising *C. philippinarum* (A. ADAMS) and "*C. circula*" (KIENER) would require a new name.

**Imbricariinae TROSCHER, 1867**  
(nom. corr.)

The subfamily includes 4 genera, three of which are Recent Indo-Pacific developments, and one genus extends as far as the Caribbean region.

A poison gland is present, and the radula consists of a unicuspid, bicuspid or multicuspid rhachidian and variable laterals according to genus. Members of all genera contained within this subfamily are sand-dwellers.

***Imbricaria* SCHUMACHER, 1817.**

*Imbricaria* SCHUMACHER, 1817, Essai Nouv. Syst., p. 236 – Type species by monotypy *I. conica* SCHUMACHER, 1817 = *I. conularis* (LAMARCK, 1811).

**Shell:** Shell small, conical in shape, solid, spire short and often depressed and concave, whorls smooth or spirally grooved and pitted, aperture long, straight and narrow, outer lip thick and smooth, columella with numerous oblique plicae, anterior canal short; shell covered with a thin periostracum.

**Radula:** Radular ribbon about 13% in length in relation to total shell-length, and about 14% in width in relation to total ribbon-length; there are about 20 rows of teeth per 1 mm of ribbon and 26 rows of teeth per 10 mm of shell-length. Rhachidians are tricuspid, 2 cusps are large and equal in size, and generally flanked by small side cusps and a smaller intermediate central cusp. Laterals 1.4 to 1.75 times the width of rhachidians, humped towards the centre and with one large inward-pointing massive cusp and 0 to 12 cusps.

**Animal:** Foot very large and extending well past the

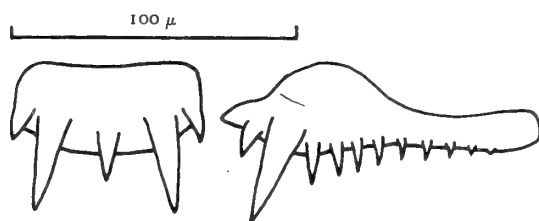


Figure 28

Half-Row of Radular Teeth of *Imbricaria conularis* (LAMARCK)

apex of the shell during the crawling position; siphon, tentacles and eyes moderately large.

**Habitat:** In sand only.

**Geographical Distribution:** Indo-Pacific.

**Age:** Recent.

**Discussion:** A description of the radula of *Imbricaria*

*conularis* (LAMARCK), *I. olivaeformis* (SWAINSON) and *I. punctata* (SWAINSON) can be found in COOKE, 1920 and CERNOHORSKY, 1966.

*Imbricaria filum* (WOOD, 1828), Ind. Test., Suppl. plt. 3, fig. 30.

Specimen from Le Goulet, Mauritius: Radular ribbon dark amber in colour, 1.8 mm long and 0.44 mm wide in shell 18.0 mm in length; fully formed rows number 39 (+ 3 nascentes) and no appreciable wear was apparent on the front rows of teeth. Rhachidians slightly heart-

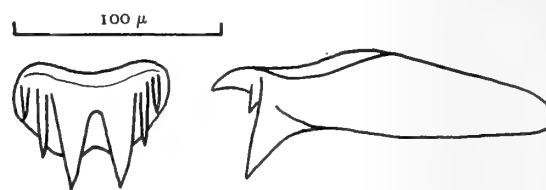


Figure 29

Half-Row of Radular Teeth of *Imbricaria filum* (Wood)

shaped with 2 prominent main cusps and 4 slender accessory cusps, 2 on either side. Laterals about  $1\frac{1}{2}$  times the width of rhachidians, wide and short, equipped with a curved process projecting towards rhachidians, and one massive cusp which is flanked by a small denticle.

This species is generally assigned to the genus *Swainsonia*; however, its relationship lies with *Imbricaria olivaeformis* (SWAINSON).

***Cancilla* SWAINSON, 1840.**

*Cancilla* SWAINSON, 1840, Treat. Malac., 127:320. – Type species by subsequent designation (HERRMANNSEN, 1846) *Tiara isabella* SWAINSON, 1831.

**Shell:** Shell slender and fusiform, sutures plain, whorls sculptured with elevated keel-like ridges, intervening grooves often axially striate; aperture narrow and fusiform, interior highly enamelled and smooth, columella plicate, anterior canal narrow and produced, outer lip generally long and crimped; shell covered with a thin epidermis.

**Animal:** In this group of species the sole of the animal's foot is almost always white or cream in colour; siphon variable, often variegated and lined with black and white, remainder of animal variable in colour.

**Radula:** Radular ribbon is fairly broad in relation to total ribbon-length, and the number of rows of teeth per 1 mm of ribbon-length is rather small (14 to 16 rows). Rhachidians variable, laterals with 1 massive long inward point-

ing cusp and resembling those of the genus *Imbricaria*.

**Habitat:** In clean and muddy sand, occasionally in sand pools of coral reefs, from the intertidal zone to deeper water.

**Geographical Distribution:** Indo-Pacific and Panamanian provinces, Caribbean?

**Age:** Eocene to Recent.

**Discussion:** The radula of the type species is unknown and should on examination the radula prove to be different, a new generic name would have to be provided for this group of shells. Species contained in this genus were placed in COOKE's group 6, which also included *Cancilla flammigera* (REEVE) and *C. interlirata* (REEVE) [vide COOKE, 1920].

*Cancilla philippinarum* (A. ADAMS, 1853); CERNOHORSKY, 1965, *The Veliger* 8 (2): 107; plt. 15, fig. 32.

Specimen from Fiji: Radular ribbon white in colour, 3.0mm long and 0.58mm wide in shell 23.0mm in

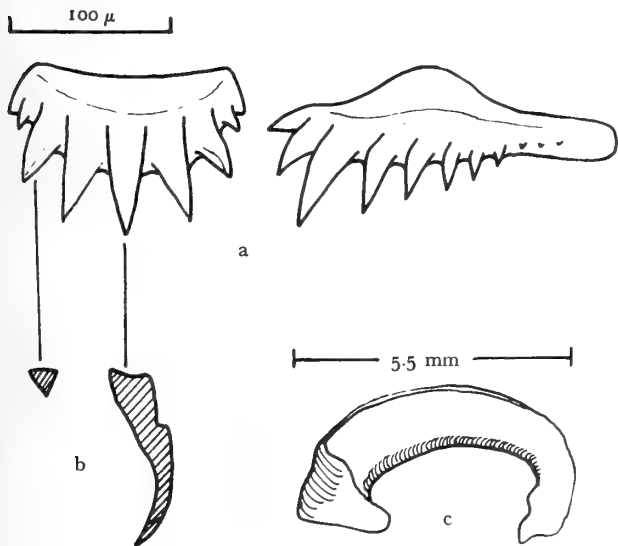


Figure 30

*Cancilla philippinarum* (A. ADAMS)

- a: Half-Row of Radular Teeth of
- b: Profile of Cusps
- c: Lateral View of Penis

length; fully formed rows number 41 (+ 2 nascentes), and no appreciable wear was evident on the rhachidians of the front rows, although some of the laterals had cusps broken off. Rhachidians moderately broad with 7 fairly large and long cusps; the 3 central cusps are almost equal in size and the last side cusps are rather small. Laterals  $1\frac{1}{2}$  times the width of the rhachidians,

with 11 to 13 cusps which are distributed almost along the entire width of the plate; one massive cusp is long and inward pointing and the ultimate 2 to 3 cusps appear only as small denticles.

*Cancilla circula* (KIENER, 1839); CERNOHORSKY, 1965, *The Veliger* 8 (2): 102; plt. 16, fig. 40.

Specimen from Fiji: Radular ribbon white, 3.0mm long and 0.39mm wide in shell 18mm in length; fully formed rows number 47 (+ 2 nascentes) and rhachidians do not show any appreciable wear in the front rows of teeth, although some cusps are broken off in laterals. Rhachidians very short and broad, with 7 slender cusps of varying length; 2 cusps are rather long and the remaining 5 cusps are much shorter and of about equal size, although the size appears to fluctuate throughout the

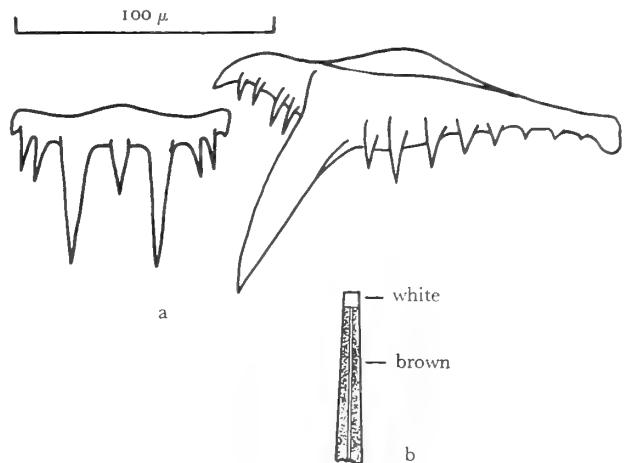


Figure 31

- a: Half-Row of Radular Teeth of "*Cancilla circula*" (KIENER)
- b: Distal End of Siphon Showing Pattern of Brown and White

rows of the same ribbon. Laterals about  $1\frac{1}{2}$  times the width of rhachidians with a curved inward-pointing beak and 11 to 14 cusps; 1 of the cusps is very long and massive and tends to be broken off in a good many rows of the ribbon.

The sole of the animal's foot is creamy-white; dorsum of foot is cream and heavily speckled and variegated with yellow. Siphon whitish underneath, brown on top with a white transverse zone at the distal end and a narrow longitudinal white central line; tentacles are short and brown, proboscis translucent white.

**Discussion:** The correct interpretation of KIENER's *Can-*

*cilla circula* is somewhat uncertain: however, the radula illustrated here came from a specimen of *C. circula* illustrated in CERNOHORSKY, 1965, and in shell characters approximating *C. sulcata* (SWAINSON).

*Cancilla strigillata* (SOWERBY, 1874); CERNOHORSKY, 1965, *The Veliger* 8 (2): 97; plt. 15, fig. 31.

Specimen from Fiji: Radular ribbon translucent white, 1.7 mm long and 0.32 mm wide in shell 16 mm in length; fully formed rows number 46 (+ 2 nascentes) and teeth

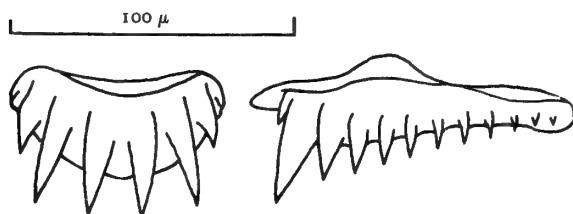


Figure 32

Half-Row of Radular Teeth of *Cancilla strigillata* (SOWERBY)

are often missing in front rows of the ribbon. Rhachidians with 6 moderately long cusps and an indication of an accessory denticle at the end of the plate. Laterals humped at the base with 12 to 14 cusps which are distributed over the entire width of the plate; 1 cusp is pointing directly towards the rhachidian while a massive and large cusp is oriented almost at right angles with a small intermediate denticle between the two.

*Scabricola* SWAINSON, 1840.

*Scabricola* SWAINSON, 1840, *Treat. Malac.*, 127: 319 – Type species by subsequent designation (GRAY, 1847) *Mitra serpentina* LAMARCK, 1811 = *Scabricola variegata* (GMELIN, 1791).

**Shell:** Shell moderate in size, elongate-ovate to cylindrical in outline, moderately solid, sculpture consisting of from 5 to 8 convexly rounded whorls and fine moderately deep spiral grooves, grooves punctate or striate; resulting spiral ridges angulate on penultimate whorl but becoming broad and flat towards the base; columella calloused and with 5 to 6 prominent plicae, outer lip crenulate or crimped, rounded anteriorly; aperture longer than the spire, early whorls granulose.

*Scabricola variegata* (GMELIN, 1791); CERNOHORSKY, 1965, *The Veliger* 8 (2): 100; plt. 14, fig. 24 a.

Radula of specimen from Mauritius: The rhachidians

and part of laterals (cusp included) rusty-brown, remainder thin and whitish; ribbon 3.2 mm long and 0.35 mm wide in shell 20.0 mm in length. Fully formed rows number 36 (+ 4 nascentes). Rhachidians triangular with one very strong and deeply-rooted central cusp. Laterals about  $1\frac{1}{2}$  times the width of rhachidians, and equipped with a curious inward-facing rounded projection and a massive long inward-pointing cusp; other cusps or denticles are absent.

**Habitat:** In clean sand, occasionally in exposed sand pits.

**Geographical Distribution:** Indo-Pacific.

**Age:** Recent.

**Discussion:** This type of radula is unique among all other mitrid radula types; both the rhachidians and laterals are unicuspid, and cusps are very strong and long. COOKE

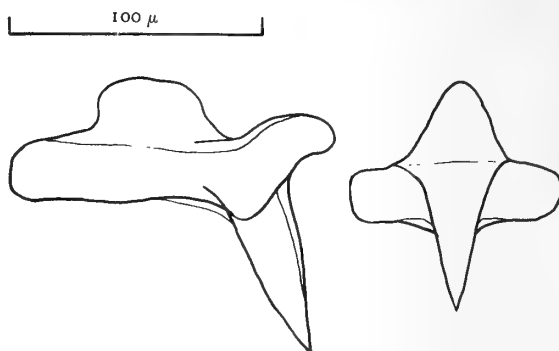


Figure 33

Half-Row of Radular Teeth of *Scabricola variegata* (GMELIN)

(1920) placed this species in his group 8; his representation of the radula (*l.c.*, fig. 14) is a rather schematic drawing.

*Swainsonia* H. & A. ADAMS, 1853.

*Swainsonia* H. & A. ADAMS, *Gen. Rec. Moll.* 1: 180 (*nom. nov. pro Mitrella* SWAINSON, 1832, *non* RISSO, 1826) – Type species by subsequent designation (COSSMANN, 1899) *Mitra fissurata* LAMARCK, 1811 = *Swainsonia fissurata* (LAMARCK, 1811).

**Shell:** Shell moderately small, oliviform, smooth and shiny, occasionally puncto-striate, spire short and pointed, aperture long and narrow, outer lip smooth and generally slightly longer than the anterior canal, columella plicate, labrum smooth; shell with a thin epidermis.

**Radula:** Rhachidians with 6 long cusps and 2 small side-cusps, plate concave, some cusps triangular in profile; laterals about the same width as rhachidians, with 3 to

5 massive beak-like cusps, first cusp the largest and gradually diminishing in size towards the base of the plate.

The radula of *Swainsonia* slightly resembles the radula of *Vasum* RÖDING, 1798, particularly the laterals.

**Habitat:** In clean or slightly muddy sand, in shallow and slightly deeper water.

**Geographical Distribution:** Indo-Pacific.

**Age:** Recent.

**Discussion:** CERNOHORSKY (1965) erroneously listed *Mitra olivaeformis* SWAINSON as the type-species of *Swainsonia*; this species should be transferred to *Imbri-caria* on radula evidence (COOKE, 1920, fig. 9 and PEILE, 1936, p. 142).

*Swainsonia fissurata* (LAMARCK, 1811); SHIKAMA, 1963, Shells world ill. col., plt. 75, fig. 7.

Specimen dredged from 17 fathoms at Rivière Noire, Mauritius: Radular ribbon rusty-brown in colour, 4.4 mm long and 0.68 mm wide in shell 27 mm in length; fully formed rows number 40 (+1 nascent) and wear was discernible in the front rows of the ribbon. Rhachidians somewhat triangular in shape, with 8 long and slender cusps and a very small accessory denticle; cusps are tri-

angular in profile. Laterals about the same size as rhachidians with 4 strong and massive cusps which diminish in size towards the bottom of the plate.

*Swainsonia newcombi* PEASE, 1865; TINKER, 1958, Pacif. Seashells, plt. facing p. 144, centre figs.

Specimen from Kailua Bay, Oahu, Hawaii: Radular ribbon rusty-brown in colour, 3.2 mm long and 0.46 mm wide in shell 20 mm in length; fully formed rows number 47 + 1 nascent) and no appreciable wear was apparent

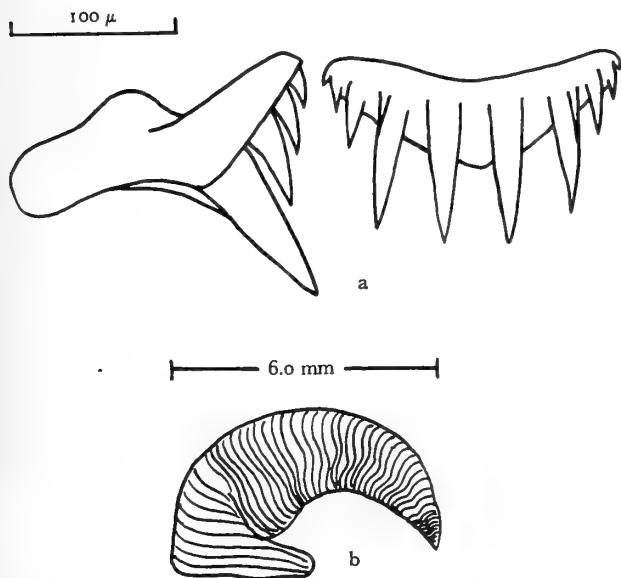


Figure 34

a: Half-Row of Radular Teeth of *Swainsonia fissurata* (LAMARCK)  
b: Lateral View of Penis



Figure 35

Half-Row of Radular Teeth of *Swainsonia newcombi* (PEASE)

on the front rows of teeth. Rhachidians somewhat triangular with 6 long and slender cusps and an indication of vestiges of small accessory cusps at the sides of the plate. Laterals slightly longer than rhachidians with 2 massive beak-like cusps.

*Swainsonia casta* (GMELIN, 1791); CERNOHORSKY, 1965 The Veliger 8 (2): 153; plt. 23, fig. 130.

Specimen from Fiji: Radular ribbon brown in colour, 5.0 mm long and 0.62 mm wide in shell 27.0 mm in length; rhachidians are hardly worn at all while only a few



Figure 36

Half-Row of Radular Teeth of *Swainsonia casta* (GMELIN)

cusps are missing in laterals. Fully formed rows number 54 (+ 2 nascentes). Rhachidians concave at base becoming somewhat arched towards the roots of the teeth, and equipped with 6 main cusps and 2 smaller but solid accessory cusps towards the base; the 2 central cusps are equal sized and in profile have a triangular cutting edge. Laterals about the same size as rhachidians, massive, unusual in shape, the plate consisting of a knuckled base and 3 prominent curved cusps which diminish in size towards the base; the main cusp is very large, solid and triangular in profile.

*Swainsonia zephyrina* (SOWERBY, 1874), Thes. Conch. 4: 4; plt. 17, figs. 307, 308.

Specimen from Le Goulet, Mauritius: Radular ribbon brown in colour, 3.8 mm long and 0.45 mm wide in shell 18 mm in length; fully formed rows number 45 (+ 2 nascentes) and early rows of teeth are hardly worn at all. Rhachidians with 8 long cusps, the two central cusps equal in size; laterals about the same size as rhachidians, with 5 massive cusps which point towards the rhachidian, and which diminish in size towards the base; the fifth cusp is often very small and hardly visible in some rows of the same ribbon.

**Discussion:** PEILE (1936, fig. 7) illustrated the radula of *Mitra mariae* A. ADAMS, 1853, which appears very similar to that of *Swainsonia zephyrina*. Apart from a slightly



Figure 37

Half-Row of Radular Teeth of *Swainsonia zephyrina* (SOWERBY)

different colouring, there seems to be little difference between *S. fusca* (SWAINSON, 1832) and *S. zephyrina* (SOWERBY, 1874).

*Mitra zonata* MARRYAT, 1819, from the Mediterranean region is frequently assigned to the genus *Swainsonia*. The radula of *M. zonata* which has been figured by VAYSSIÈRE (1901), has rhachidians with 7 moderately long cusps and laterals with 20 to 21 cusps; the radula is in fact very similar to that of *M. cardinalis* (GMELIN), and belongs to *Mitra* s. str.

#### Vexillinae THIELE, 1929.

The subfamily comprises 2 genera and 3 subgenera, with *Vexillum* representing the oldest genus of the subfamily, and *Pusia* its latest offshoot. Species are numerous, mainly tropical and subtropical in distribution. A poison gland is absent in members of the subfamily; the foot, tentacles and eyes are generally larger than those of the Mitrinae, and species of Vexillinae primarily inhabit sand substrata.

The radula of the Vexillinae consists of a wide and multicuspid or narrow and tricuspid rhachidian and sickle-shaped curved laterals which are in the process of reduction.

#### *Vexillum* RÖDING, 1798.

*Vexillum* RÖDING, 1798, Mus. Bolten., p. 138 - Type species by subsequent designation (WOODRING, 1928) *Vexillum plicatum* RÖDING, 1798 = *Vexillum plicarium* (LINNAEUS, 1758).

**Shell:** Shell 10 mm to 80 mm in size, fusiform or elongate-ovate, sutures plain or tuberculate, sculptured with axial plicae or striae and transverse grooves or ridges; aperture narrow or moderately wide and elongate, often constricted basally, labrum lirate, columella plicate; anterior canal narrow and produced, often recurved; shell covered with a thin epidermis.

**Animal:** Foot moderately large and multicoloured, tentacles long and slender; eyes and siphon moderately large, proboscis small.

**Radula:** Length of radular ribbon small, generally not exceeding 10% of shell-length. Rhachidians are of the "rastriform" type, bow- or wing-shaped, with numerous cusps distributed almost along the entire width of the plate; lateral teeth small, curved and sickle-shaped, overlapping the rhachidians for a short distance. The radula of *Vexillum* is rather similar to the radula of the genus *Nux* BARNARD, 1960; the rhachidians bear a certain resemblance to those of *Cyllene* GRAY, 1833 (Nassidae).

**Habitat:** In clean and muddy sand of lagoons and sandbanks and in sand-pockets of coral reefs, from shallow to deeper water.

**Geographical Distribution:** Since Late Miocene confined to the Indo-Pacific, Panamic, Caribbean and Atlantic regions.

**Age:** Eocene to Recent.

**Discussion:** The radula of *Vexillum sanguisugum* (LINNAEUS), the type species of *Pulchritima* IREDALE, was figured by PEILE (1936, fig. 11) and it is that of *Vexillum* s. str.; this genus is superfluous and should be placed in its proper synonymy. The radula of *Mitropifex quasillus*



IREDALE, the type species of *Mitropifex* IREDALE, 1929, is unknown to me; however, the radula of *Mitropifex collinsoni* (A. ADAMS) as figured by HABE (1943, plt. 3, fig. 13) does not differ from *Vexillum* in any way.

*Vexillum exasperatum* (GMELIN, 1791); CERNOHORSKY, 1965, *The Veliger* 8 (2): 124; plt. 19, fig. 77.

Specimen from Fiji: Radular ribbon translucent-white in colour, 1.1 mm long and 0.09 mm wide in shell 21 mm in length; fully formed rows number 45 (+ 3 nascentes), and no apparent wear in the front rows of teeth was discernible apart from some missing laterals. Rhachidians broad and bow-shaped,  $2\frac{1}{2}$  times the width of laterals, with 19 to 21 slender and moderately long cusps; the

in length; fully formed rows number 46 (+ 2 nascentes), and appreciable wear was evident in the front rows. Rhachidians bow-shaped with 21 rather slender cusps, central of which is broader and longer than the rest. Laterals smaller than rhachidians, unicuspid and with a knuckle-like hump at the base of the tooth.

*Vexillum semifasciatum* (LAMARCK, 1811); CERNOHORSKY, 1965, *The Veliger* 8 (2): 135; plt. 22, fig. 112.

Specimen from Fiji: Radular ribbon yellowish in colour, 0.72 mm long and 0.13 mm wide in shell 19 mm in length; fully formed rows number 67 (+ 2 nascentes) and no appreciable wear was evident on the front rows of teeth. Rhachidians bow-shaped, with 15 to 17 equal-sized cusps

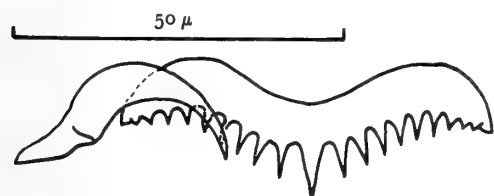


Figure 38

Half-Row of Radular Teeth of *Vexillum exasperatum* (GMELIN)

central cusp is broader and longer while the end-cusps appear only as small denticles. Laterals sickle-shaped and overlapping rhachidians to about the sixth cusp.

This species is the type species of *Arenimitra* IREDALE, 1929, which becomes synonymous with *Vexillum* RÖDING.

*Vexillum cadaverosum* (REEVE, 1844); CERNOHORSKY, 1965, *The Veliger* 8 (2): 118; plt. 18, fig. 71.

Specimen from Fiji: Radular ribbon translucent-white in colour, 1.27 mm long and 0.19 mm wide in shell 17 mm

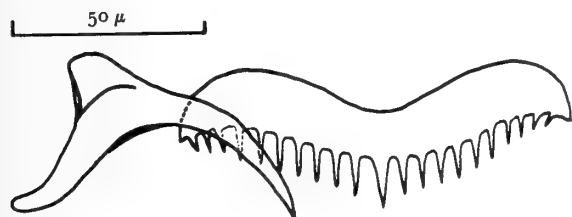


Figure 39

Half-Row of Radular Teeth of *Vexillum cadaverosum* (REEVE)

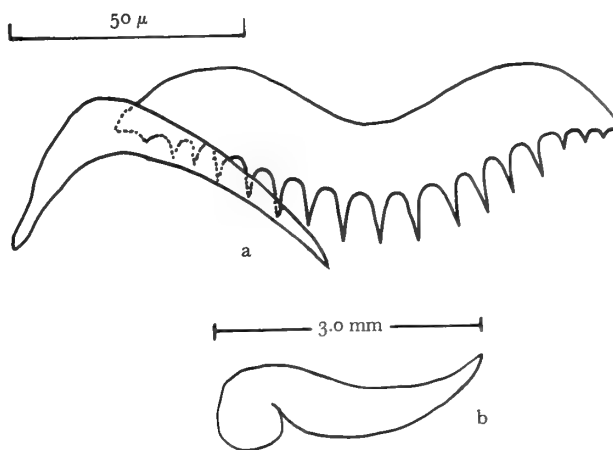


Figure 40

*Vexillum semifasciatum* (LAMARCK)

a: Half-Row of Radular Teeth

b: Lateral View of Penis

which are distributed along the entire width of the plate. Laterals smaller than rhachidians, unicuspid, slender and overlapping rhachidians.

*Vexillum semifasciatum* (LAMARCK) is the type species of *Costellaria* SWAINSON, 1840 by monotypy (as *Costellaria rigida* SWAINSON, 1822). For the latter species SWAINSON offered an illustration which is beyond doubt the species *Mitra semifasciata* LAMARCK (*vide* SWAINSON, 1822, plt. 29, centre figures). The *Mitra rigida* SWAINSON of 1840, however (text fig. 84d), is the species *Vexillum deshayesi* (REEVE, 1844). The genus *Costellaria* should be placed in the synonymy of *Vexillum* s. str.

*Vexillum luculentum* (REEVE, 1845); CERNOHORSKY, 1965, *The Veliger* 8 (2): 147; plt. 22, fig. 122.

Specimen from Fiji: Radular ribbon translucent-white, 0.9 mm long and 0.12 mm wide in shell 13 mm in length; fully formed rows number 58 (+ 2 nascentes), and the two front rows of teeth show appreciable wear on the rhachidians. Rhachidians bow-shaped with 9 moderately large cusps of about equal length with the exception of the last cusp which is appreciably smaller; the ends of the plate are bare. Laterals smaller than rhachidians, unicuspid, slender and overlapping rhachidians.

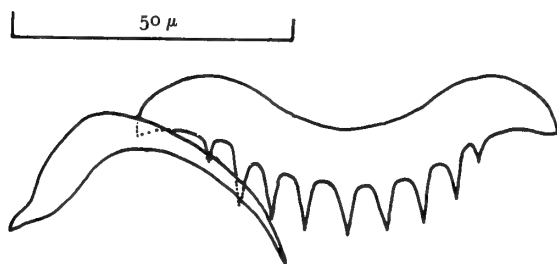


Figure 41

Half-Row of Radular Teeth of *Vexillum luculentum* (REEVE)

**Discussion:** The radula of *Vexillum luculentum* (REEVE) clearly demonstrates the difficulty in assigning members of this group to the proper genus, since on conchological grounds this species is always assigned to the genus *Pusia* SWAINSON. *Pusia crocata* (LAMARCK) is another species which must be removed to *Vexillum*, as the radula is similar to that of *V. costellaris* (LAMARCK) (*vide* PEILE, 1936). COOKE (1920) examined the radula of *Pusia cancellarioides* (ANTON) [reported as *Vexillum nodosum* (SWAINSON)] from Hawaii, and found the rhachidians to possess 7 to 8 cusps and to belong to *Vexillum*.

It is highly probable that the radula of the type species of *Pusia*, i.e. *P. microzonias* (LAMARCK), will have a radula of the *Vexillum* pattern. In that case the genus *Pusiolina* (type species *Voluta tricolor* GMELIN, 1791) would have to be used for species possessing a radula consisting of a tricuspid rhachidian.

(*Zierliana*) GRAY, 1847.

*Zierliana* GRAY, 1847, *Proc. Zool. Soc. London*, p. 141 – Type species by original designation *Voluta ziervoyelii* GMELIN, 1791 = *Vexillum (Zierliana) ziervoyelii* (GMELIN) [emended DILLWYN, 1817].

**Shell:** Shell moderately small, oviform, spire shorter than the aperture, whorls coarsely axially plicate; columella with 4 oblique folds, posteriorly calloused, outer lip thickened and dentate on inner margin.

**Radula:** THIELE (1931) places the subgenus as a section of *Vexillum*, and remarks that the rhachidian tooth of *Zierliana* is multicuspid.

**Habitat:** Generally inhabits sand substrate under basalt or coral rocks towards the high tide region.

**Geographical Distribution:** Indo-Pacific.

**Age:** Recent.

*Pusia* SWAINSON, 1840.

*Pusia* SWAINSON, 1840, *Treat. Malac.* 127: 320 – Type species by monotypy *Mitra microzonis* [sic] LAMARCK, 1811 = *Pusia microzonias* (LAMARCK, 1811).

**Shell:** Shell moderately small, depressed, elongate-ovate to ovate, solid, sutures smooth, tuberculate or coronate, whorls smooth, axially plicate or nodulose, spirally striate or ridged, outer lip thick or thin, labrum lirate or rarely smooth, columella plicate, anterior canal short; shell covered with a thin epidermis.

**Radula:** Radula consists of tricuspid rhachidians, base of plate concave, length of cusps variable, central cusp generally slightly larger; lateral teeth about equal in size to rhachidian or only slightly smaller, and in the form of simple hook-like teeth. The radula of *Pusia* resembles the radulae of some species of *Metzgeria* NORMAN, 1879 (Vasidae), *Rapana* SCHUMACHER, 1817 and *Columbarium* VON MARTENS, 1881 (Muricidae), and somewhat less those of *Oliva* BRUGUIÈRE, 1789. The rhachidian on its own is rather similar to that of *Volutocorbis* DALL, 1890 (Volutidae).

Radulae of *Pusia* have been figured by PEILE (1922), THIELE (1931), HABE (1943) and BARNARD (1959).



Figure 42

Half-Row of Radular Teeth of *Pusia hizenensis* (PILSBRY)  
[after HABE, 1943, plate 3; figure 10]



Figure 43

Half-Row of Radular Teeth of *Pusia tricolor* (GMELIN)  
[after PEILE, 1922, figure 5]

**Habitat:** In sand-pockets of coral reefs and cracks and crevices of coral reef flats and underside of coral rocks, from the intertidal zone to deeper water.

**Geographical Distribution:** Indo-Pacific, Panamic, Caribbean and Mediterranean regions.

**Age:** Late Miocene to Recent.

**Discussion:** The true *Pusia* may have developed independently in the Indo-Pacific from *Vexillum* and re-entered the European-Mediterranean region prior to the disappearance of the Tethys sea. Radulae of *Pusia* pattern formed group 12 in COOKE's arrangement.

(*Thala*) H. & A. ADAMS, 1853.

*Thala* H. & A. ADAMS, 1853, Gen. Rec. Moll. 1: 178 – Type species by subsequent designation (COSSMANN, 1899) *Mitra mirifica* REEVE, 1845.

**Shell:** Shell small, fusiform, apex produced and smooth, sculpture consisting of spiral rows of nodules, body whorl produced anteriorly, columella plicate, aperture narrow, outer lip thick and denticulate, anterior canal produced and recurved.

**Radula:** Radula pattern very similar to that of *Pusia*; the rhachidians are bow-shaped with the ends bent slightly backwards, and equipped with 3 prominent cusps which on rare occasions are flanked by very small side-denticles; laterals as in *Pusia*.



Figure 44

*Pusia (Thala) ogasawarana* (PILSBRY)  
Half-Row of Radular Teeth  
[after HABE, 1943, plate 3, figure 11]

*Pusia (Thala) simulans* (VON MARTENS)  
Half-Row of Radular Teeth  
[after THIELE, 1931, figure 394]



Figure 45

**Habitat:** Under coral rocks on sand substratum.

**Geographical Distribution:** Indo-Pacific and Panamic regions.

**Age:** Recent.

**Discussion:** This subgenus comprises only a very few species. The species *Thala ogasawarana* var. PILSBRY, 1904, figured by HABE (1961, pl. 34, fig. 1) appears to

be conspecific with *Mitra secalina* GOULD, 1860, from the Ryukyu Islands.

(*Idiochila*) PILSBRY, 1921.

*Idiochila* PILSBRY, 1921, Proc. Acad. Nat. Sci. Philad. 72: 315. – Type species by original designation *Mitra turben* REEVE, 1844.

**Shell:** Shell small, solid, oviform and obese, axially closely plicate, interstices striate, sutures prominently deep; spirally ridged towards the base, aperture narrow, outer lip contracted anteriorly, labrum lirate, parietal wall callosed, columella with 5 to 6 prominent folds, anterior canal somewhat produced.

**Radula:** The radula of the type species is unknown; however, most conchological characters suggest a relationship with *Pusia* rather than with *Vexillum*; the assignment under *Pusia* is therefore only tentative.

**Habitat:** Under coral rocks on sand and broken coral substrate, in shallow and deeper water.

**Geographical Distribution:** Indo-Pacific.

**Age:** ? Recent.

Cylindromitrinae COSSMANN, 1899.

This subfamily comprises only one Recent genus which developed in the Indo-Pacific region. The shells are characterized by their cylindrical appearance and the radula by the lack of lateral teeth.

*Pterygia* RÖDING, 1798.

*Pterygia* RÖDING, 1798, Mus. Bolten., p. 51. – Type species by subsequent designation (DALL, 1915) *Pterygia nucella* RÖDING, 1798 = *P. dactylus* (LINNAEUS, 1767).

**Shell:** Shell moderate in size, cylindrically-ovate, solid, thick, spire short, body whorl smooth or sculptured with spiral ridges or striae; outer lip long and thick, smooth or crenulate, columella with numerous oblique plicae; shell covered with a thin epidermis.

**Animal:** Foot generally large, tentacles short, proboscis very slender and extremely long (occasionally 3 to 4 times the length of the shell).

**Radula:** The radular teeth differ from all other mitrid radulae in the absence of lateral teeth; rhachidians are slightly similar in form to those of the genus *Swainsonia* and are equipped with 5 to 9 cusps. The radular ribbon is fragile and very small in relation to shell-length.

**Habitat:** In clean sand, from shallow to deeper water.

**Geographical Distribution:** Indo-Pacific.

**Age:** Recent.

*Pterygia nucea* (GMELIN, 1791); CERNOHORSKY, 1965, *The Veliger* 8 (2): 153; plt. 23, fig. 128.

Specimen from Fiji: Radular ribbon white in colour, 1.2 mm long and 0.06 mm wide in shell 40 mm in length; fully formed rows number 75 (+ 2 nascentes). Rhachidians roughly elliptical, prominently curved inward, with 2 knob-like protrusions at either end, and 9 moderately small cusps; the central cusp is the longest and remainder of cusps protrude only slightly past the edge of the plate. The teeth are so prominently curved that if too much pressure is applied to the cover slide, the rhachidians will tend to split centrally. Lateral teeth absent.

The proboscis is very long and slender, 85 mm long and 0.9 mm wide in fully extended position in a shell 40 mm in length.

**Discussion:** PEILE (1922) remarked that the radula of *Pterygia dactylus* (LINNAEUS) preserved in the British Museum (Natural History) collection also lacks laterals.

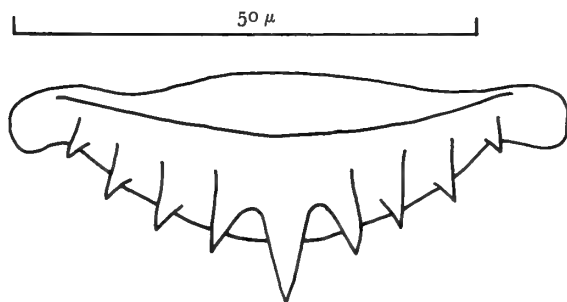


Figure 46

One Row of Radular Teeth of *Pterygia nucea* (GMELIN)

THIELE (1931) figures the radula of *P. crenulata* (GMELIN) which lacks laterals; the rhachidian in this species has 5 cusps, with the central cusp the longest.

*Pterygia nucea* (GMELIN) is the type species of *Acuticylindra* IREDALE, 1929; the species, however, is obviously congeneric with *P. dactylus* (LINNAEUS), the type species of *Pterygia*.

*Pterygia scabricula* (LINNAEUS, 1758); CERNOHORSKY, 1965, *The Veliger* 8 (2): 153; plt. 13, fig. 6.

Specimen from Fiji: Radular ribbon translucent white in colour, 1.5 mm long and 0.09 mm wide in shell 20 mm in length; fully formed rows number 88 (+ 4 nascentes)

and no wear was evident on the front rows of teeth. Rhachidians concave, with 7 sharp cusps, central cusp the largest, remainder diminishing in size towards the end of the plate. Lateral teeth absent.

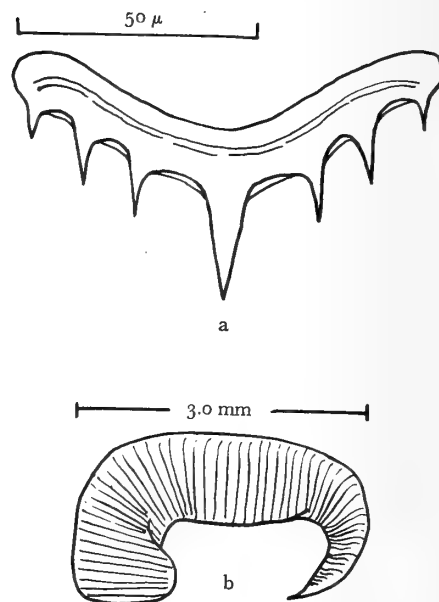


Figure 47

*Pterygia scabricula* (LINNAEUS)  
a: One Row of Radular Teeth  
b: Lateral View of Penis

The proboscis measured 17 mm in a shell 20 mm in length. This species is generally placed in either *Mitra* s. str. or *Scabricola*. It should be removed from Mitrinac and assigned to Cylandromitrinae.

#### SYNONYMIC LIST

#### OF THE PROPOSED ARRANGEMENT OF THE FAMILY MITRIDAE

(Type species are shown in brackets; genera based on a fossil type species are indicated with †)

Mitrinac SWAINSON, 1831.

#### Genus

*Mitra* RÖDING, 1798 – Type species *Mitra mitra* (LINNAEUS, 1758)

*Mitra* MARTYN, 1784 [(non binomial) – *M. tessellata* MARTYN, 1784 = *Voluta incompta* SOLANDER in LIGHTFOOT, 1786]

*Mitra* RÖDING, 1798 [*Voluta episcopalis* LINNAEUS, 1758 = *Voluta mitra* LINNAEUS, 1758]

*Mitraria* RAFINESQUE, 1815 [*Voluta episcopalis* LINNAEUS, 1758 = *V. mitra* LINNAEUS, 1758]

*Thiarella* SWAINSON, 1840 (in err. pro *Tiarella*, first reviser HERRMANNSEN, 1847)

*Tiarella* SWAINSON, 1840 (no type designated; synonymous with *Mitra* RÖDING, 1798)

*Tiara* SWAINSON, 1840 (pars) [non *Tiara* SWAINSON, 1831]

*Nebularia* SWAINSON, 1840 [*Mitra contracta* SWAINSON, 1820]

*Chrysame* H. & A. ADAMS, 1853 [*Mitra coronata* LAMARCK 1811]

*Isara* H. & A. ADAMS, 1853 [*Mitra bulimoides* REEVE, 1845]

*Ziba* H. & A. ADAMS, 1853 [*Mitra carinata* SWAINSON, 1824]

*Phaeomitra* VON MARTENS, 1880 (no type designated; *Mitra fulva* SWAINSON, 1829 = *M. coffea* SCHUBERT & WAGNER, 1829 is the first species listed)

*Cucurbita* SCUDDER, 1882 (nom. nud.)

† *Eumitra* TATE, 1889 [*Mitra alokiza* TENISON-WOODS, 1889]

*Fuscomitra* PALLARY, 1900 [*Mitrella fusca* SWAINSON, 1824]

*Papalaria* DALL, 1915 [(no type designated; applies to the group of "the smooth red-spotted Mitras regarded hitherto as typical" (DALL, 1915)]

*Episcomitra* MONTEROSATO, 1917 [*Mitra zonata* MARRYAT, 1819]

*Atrimitra* DALL, 1918 [*Mitra idae* MELVILL, 1893]

† *Diplomitra* FINLAY, 1927 [*Cymbiola nitens*, MARSHALL, 1918]

*Vicimitra* IREDALE, 1929 [*V. prosphora* IREDALE, 1929]

#### Subgenus

(*Dibaphus*) PHILIPPI, 1847 – Type species *Conohelix edentula* SWAINSON = *Conus edentulus* REEVE, 1844

*Mutyca* H. & A. ADAMS, 1853 [*Mitra ancillides* BRODERIP, 1836]

*Mitroidea* PEASE, 1865 [*M. multiplicata* PEASE, 1865]

*Mauritia* H. ADAMS, 1869 (non TROSCHER, 1863) [*M. barclayi* H. ADAMS, 1869]

#### Genus

*Strigatella* SWAINSON, 1840 – Type species *Mitra zebra* LAMARCK, 1811 = *Voluta paupercula* LINNAEUS, 1758

† [?] *Mitreola* SWAINSON, 1832 [*M. monodonta* LAMARCK, 1803]

#### Genus

*Neocancilla* CERNOHORSKY, 1966 – Type species *Voluta papilio* LINK, 1807

#### Genus

? : Group 10 of COOKE, 1920 – ? *Mitra scabriuscula* LAMARCK = ? *M. granatina* LAMARCK, 1811

#### Genus

*Charitodoron* TOMLIN, 1932 – Type species *C. euphrosyne* TOMLIN, 1932 [originally established as genus in Buccinidae].

### Imbricariinae TROSCHER, 1867

#### Genus

*Imbricaria* SCHUMACHER, 1817 – Type species *I. conica* SCHUMACHER, 1817 = *I. conularis* (LAMARCK, 1811)

*Conoelix* SWAINSON, 1821 [*C. lineatus* SWAINSON, 1821 = *Mitra conularis* LAMARCK, 1811]

*Conohelix* SOWERBY, 1825 [in err. pro *Conoelix* SWAINSON, 1821]

*Conoehelix* SWAINSON, 1840 [in err. pro *Conoelix* SWAINSON, 1821]

*Mitricaria* YATES, 1885 [? in err. pro *Imbricaria* SCHUMACHER, 1817]

#### Genus

*Cancilla* SWAINSON, 1840 – Type species *Tiara isabella* SWAINSON, 1831 [?] *Tiara* SWAINSON, 1831 (pars)

#### Genus

*Scabricola* SWAINSON, 1840 – Type species *Mitra serpentina* LAMARCK, 1811 = *Scabricola variegata* (GMELIN, 1791)

*Scabricula* SOWERBY, 1842 (in err. pro *Scabricola* SWAINSON, 1840)

*Scabicola* GRAY, 1847 (in err. pro *Scabricola* SWAINSON, 1840)

#### Genus

*Swainsonia* H. & A. ADAMS, 1853 – Type species *Mitra fissurata* LAMARCK = *Swainsonia fissurata* (LAMARCK, 1811)

*Mitrella* SWAINSON, 1831 (non RISSO, 1826) – [*M. fissurella* LAMARCK = *Mitra fissurata* LAMARCK, 1811]

*Swainsonia* H. & A. ADAMS, 1853 (nom. nov. pro *Mitrella* SWAINSON, 1831)

## Vexillinae THIELE, 1929

## Genus

- Vexillum* RÖDING, 1798 – Type species *V. plicatum* RÖDING, 1798 = *V. plicarium* (LINNAEUS, 1758)  
*Turricula* KLEIN, 1753 (pre-Linnaean)  
*Vexillum* RÖDING, 1798 [*V. plicatum* RÖDING, 1798 = *Voluta plicaria* LINNAEUS, 1758]  
*Turris* MONTFORT, 1810 (non RÖDING, 1798) – *Voluta vulpecula* LINNAEUS, 1758]  
*Vulpecula* BLAINVILLE, 1824 [*Voluta vulpecula* LINNAEUS, 1758]  
*Tiara* SWAINSON, 1831 [*Mitra corrugata* LAMARCK, 1811 = *Voluta rugosa* GMELIN, 1791]  
*Thiara* SWAINSON, 1840 (non RÖDING, 1798) (in err. pro *Tiara* SWAINSON)  
*Callithea* SWAINSON, 1840 (non BOISDUVAL, 1835) [*Voluta sanguisuga* LINNAEUS, 1758]  
*Costellaria* SWAINSON, 1840 [*Mitra rigida* SWAINSON, 1821 = *M. semifasciata* LAMARCK, 1811]  
*Turricula* auctt. (non SCHUMACHER, 1817)  
† *Mesorhytis* MEEK, 1876 [*Fasciolaria* (*M.*) *gracilentia* MEEK, 1876]  
*Latiromitra* LOCARD, 1897 [*L. specialis* LOCARD, 1897 – originally introduced as a genus in Pisanidae]  
† *Waimatea* FINLAY, 1927 [*Mitra inconspicua* HUTTON, 1885]  
*Pulchritima* IREDALE, 1929 (nom. nov. pro *Callithea* SWAINSON, 1840)  
*Arenimitra* IREDALE, 1929 [*Mitra arenosa* LAMARCK, 1811 = *Voluta exasperata* GMELIN, 1791]  
*Mitropifex* IREDALE, 1929 [*M. quasillus* IREDALE, 1929]  
† *Parvimitra* FINLAY, 1930 [*P. pukeuriensis* FINLAY, 1930]

## Subgenus

- (*Zierliana*) GRAY, 1847 – Type species *Voluta ziervoyelii* GMELIN, 1791 = *Zierliana ziervogelii* (GMELIN, 1791) – emend. DILLWYN, 1817  
† *Conomitra* CONRAD, 1865 [*Mitra fusoides* LEA, 1833]  
*Ziervogelia* P. FISCHER, 1884 (emend. van. pro *Zierliana* GRAY, 1847)

## Genus

- Pusia* SWAINSON, 1840 – Type species *Tiara* (*Pusia*) *microzonis* (sic) LAMARCK, 1811 = *Mitra microzonias* LAMARCK, 1811  
*Pusiola* MONTEROSATO, 1917 (non WALLENGREN, 1863) [*Voluta tricolor* GMELIN, 1791]  
*Pusiolina* COSSMANN, 1921 (nom. nov. pro *Pusiola* MONTEROSATO, 1917)  
*Peculator* IREDALE, 1924 [*P. verconis* IREDALE, 1924]

*Austromitra* FINLAY, 1927 [*Columbella rubiginosa* HUTTON, 1873 = *Mitra analogica* REEVE, 1845]

† *Balcomitra* FINLAY, 1927 [*Mitra paucicostata* TATE, 1889]

† *Proximitra* FINLAY, 1927 [*Vexillum rutidolomum* SUTTER, 1885]

## Subgenus

(*Thala*) H. & A. ADAMS, 1853 – Type species *Mitra mirifica* REEVE, 1845

## Subgenus

(*Idiochila*) PILSBRY, 1921 – Type species *Mitra turben* REEVE, 1844

## Cylindromitrinae COSSMANN, 1899

## Genus

- Pterygia* RÖDING, 1798 – Type species *P. nucella* RÖDING, 1798 = *P. dactylus* (LINNAEUS, 1767)  
*Cylindra* SCHUMACHER, 1817 (non ILLIGER, 1802) [*C. coronata* SCHUMACHER, 1817 = *Voluta crenulata* GMELIN, 1791]  
*Cylindromitra* P. FISCHER, 1884 [*Voluta crenulata* GMELIN, 1791]  
*Cylinder* MELVILL & STANDEN, 1895 (non MONTFORT, 1810) (in err. pro *Cylindra* SCHUMACHER, 1817)  
*Acuticylindra* IREDALE, 1929 [*Voluta nucea* GMELIN, 1791]  
*Pterygia* DAUTZENBERG, 1935 (in err. pro *Pterygia* RÖDING, 1798)

## Genera Established in or Occasionally Assigned to

## THE FAMILY MITRIDAE

- Aidone* H. & A. ADAMS, 1853 [*Mitra insignis* A. ADAMS, 1853] – Fam. Columbelloidae  
*Volutomitra* H. & A. ADAMS, 1853 [*Mitra groenlandica* BECK in MÖLLER, 1842] – Fam. Volutidae  
*Mitropsis* PEASE, 1867 [*M. fusiformis* PEASE, 1867 = *Columbella pauimotensis* TRYON, 1883] – Fam. Columbelloidae  
*Microvoluta* ANGAS, 1877 [*M. australis* ANGAS, 1877] – Fam. Volutidae  
*Mitrolumna* BUCQUOY, DAUTZENBERG & DOLLFUSS, 1883 [*Mitra olivoidea* CANTRAINE, 1835] – *Mitromorpha* A. ADAMS, 1865; Fam. Turridae  
*Clinomitra* BELLARDI, 1889 [*C. rovasendae* BELLARDI, 1889] – Fam. Turridae  
*Diptychomitra* BELLARDI, 1889 [*D. eximia* BELLARDI, 1889] – Fam. Columbelloidae

The genera *Volutomitra* H. & A. ADAMS and *Microvoluta* ANGAS, are assigned to the family Mitridae by COTTON (1957). Both these genera belong to the subfamily Volutomitrinae within the family Volutidae. The rhachidians of *Volutomitra typica* STREBEL, 1908 (= *fragilima* WATSON, 1882) and *V. groenlandica* (BECK in MÖLLER, 1842) resemble that of *Amoria turneri* (GRAY in GRIFFITH & PIDGEON, 1834) very closely; the rhachidian plate is wishbone or "Y"-shaped, with one single pointed cusp, while laterals are small and obliquely rhomboidal. Members of Volutomitrinae inhabit temperate and sub-arctic waters.

### SUMMARY

In view of the group's geologic history, zoogeography, diversity in radula pattern, differences in animal structure and variability of ecological requirement, it would be malacologically unsound to combine the 500-odd Recent species under one genus *Mitra*. The single genus theory advocated by some writers would in addition create taxonomic problems because of secondary homonymy.

The proposed subdivision may appear rather orthodox with 45 to 50 species per genus. It is expected, however, that with more attention being devoted to the soft parts by future investigators, the taxonomic value of several old-established genera may be either confirmed or rejected; it may also be necessary to establish new genera for the reception of well-defined natural groups of mitrids. In conclusion it may be said that sufficient evidence has been advanced to realize that the present generic assignment of species whose radulae remain unknown will at times prove to be erroneous.

### ACKNOWLEDGMENTS

I would like to thank Dr. D. McMichael, Australian Museum, Sydney, and Drs. H. Rehder and J. Rosewater, Smithsonian Institution, Washington, for the often time-consuming compilation of reference material.

I wish to acknowledge with thanks Dr. Myra Keen's interest in this project and express my gratitude to Mr. E. Coan for his co-operation in this proposed revision of the family, and for information on references unavailable to me.

I wish to thank the following collectors for preserved mitrid material: Mr. and Mrs. R. F. Browne, Nausori; Mrs. J. Cate, Los Angeles; Mrs. E. Couacaud, Mauritius; Mr. W. Eyerdam, Seattle; Mr. and Mrs. F. Freitag, Suva;

Mr. G. Griffen, Suva; Mr. and Mrs. N. Hunter, Avoca Beach; Mr. A. Jennings, Nadi Airport; and Mr. C. Weaver, Hawaii.

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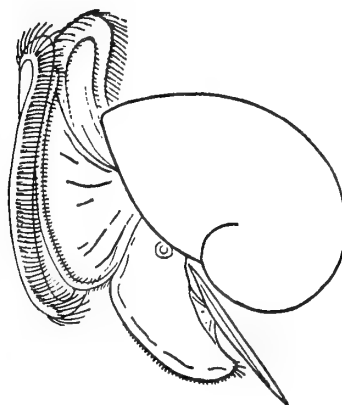
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# Nomenclatural Units in the Gastropod Family Mitridae

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## INTRODUCTION

THE BIBLIOGRAPHIC WORK upon which this report is based was begun in preparation for a review of the family in the *Treatise on Invertebrate Paleontology*. In addition to writing a treatment for eventual publication in the *Treatise*, Mrs. Jean M. Cate and I had intended to publish an advance outline much like reports I have prepared on other gastropod families (COAN, 1964, 1965 a, 1965 b).

Up to the time that this work was nearly completed, we were unaware that Mr. Walter O. Cernohorsky of Vatu-koula, Fiji Islands, was engaged in a study of the Mitridae, especially of the radulae. In spite of the fact that CERNOHORSKY (1966, this issue, above) has included a fairly complete list of taxa above the specific level, I consider that the present paper should be published because it supplements his treatment in two major respects. First, I have covered all genera, living and fossil, whereas Cernohorsky mentions only a few of the fossil genera. Secondly, I had access to the facilities of the Stanford University Libraries and could compile what I hope is a complete bibliography.

Thanks to the kindness of Mr. Cernohorsky, I have had an opportunity to study his paper in advance of its publication, and we have exchanged information on various nomenclatural questions. On the whole, we are now in agreement with regard to these questions, but there are still some points about which there is disagreement, and I will discuss these below.

I must repeat, however, that my contribution to mitrid literature is entirely bibliographical. I have not had the opportunity to study the anatomy nor the time to study the shells of these forms. For this reason, it is not my intention to discuss classification here. There are several points about which I now anticipate some disparity with Cernohorsky's scheme, chiefly stemming from the fact that he has studied only the living Indo-Pacific forms.

## ACKNOWLEDGMENTS

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## CONVENTIONS AND ABBREVIATIONS

The following treatment consists of two lists. The first is of family-level units in taxonomic order; the second of generic names in alphabetical order. Points to be discussed are in numbered footnotes.

The conventions and abbreviations used in this paper are, for the most part, those used in the *Treatise on Invertebrate Paleontology*.

The name of the type species of a given genus is set off by an asterisk and square brackets ([\*]); the form of the type designation is then indicated by means of the abbreviations listed below.

The work in which the associated taxon was named or subsequent designation made is indicated by a date (and a letter, if necessary). The numbers following such dates refer to the pages or plates in the work where the name or designation appears. Often numbers of species in these works are given. All works are listed under Literature Cited.

If the name of the author of a species is not given, it is to be assumed that the species was first described by the author of the associated genus and in the same work; in this case, abbreviations of genera are not filled out. The type species, however, are usually first listed as they were designated – originally or subsequently – with the exception that abbreviations are filled out and names of the authors of the species have been added where they were

lacking. This entry is often followed by the original combination of the species and earlier synonyms. Being somewhat unfamiliar with the nomenclature of the species of the Mitridae, I may not have indicated some earlier synonyms, although most have been checked by Mrs. Jean M. Cate.

Abbreviations used are as follows:

- (?) (before a name) – position or synonymy questioned
- = – synonym of
- 1st rev. – first reviser is [ICZN Arts. 24 and 32 d]
- Art(s). – Article(s) of ICZN
- auctt. (*auctores*) – of authors
- emend. – emendation
- ex – from
- fide – according to
- ICZN – International Code of Zoological Nomenclature (see STOLL *et al.*, 1964) or International Commission of Zoological Nomenclature
- in synon. – a generic name proposed in the synonymy of another and therefore unavailable (unless adopted prior to 1961) [ICZN Art. 11 d]
- M – type fixed by monotypy [ICZN Art. 68 c]
- MS – the manuscript of
- no(s). – number(s)
- nom. correct. – a name with an intentionally altered spelling of the sort allowed under the ICZN [ICZN Art. 11 e]
- (*nomen correctum*)
- nom. nov. – a new name [ICZN Art. 60 b]
- (*nomen novum*)
- nom. nud. – a name which, as originally published, fails to meet the requirements of the ICZN and is unavailable for use [ICZN Arts. 10 to 16]
- (*nomen nudum*)
- nom. null. – a spelling error, having no status in nomenclature [ICZN Art. 33 b]
- (*nomen nullum*)
- nom. subst. – replacement name published as a substitute for an invalid name [ICZN Art. 16 a (iii), subject to 67 i for purposes of type designation]
- (*nomen substitutum*)

nom. transl.

(*nomen translatum*)

- a name derived by valid emendation of a previously published name as the result of transfer from one taxonomic category to another within the “family-level” [ICZN Art. 36]

nom. van.

(*nomen vanum*)

- an invalid emendation having status in nomenclature only as a junior objective synonym [ICZN Art. 33 a (ii)]

non

OD

- not of

- type fixed by original designation [ICZN Art. 68 a]

Op.

p(p).

plt (s).

preocc.

pro

rej.

SD

- Opinion no.

- page(s)

- plate(s)

- preoccupied

- for

- rejected by

- type fixed by the subsequent designation of [ICZN Art. 69 a]

SF

T

- subfamily

- type fixed by tautonymy [ICZN Art. 68 d]

## I. FAMILY-LEVEL NAMES

Mitridae SWAINSON, 1831: pls. 49, 50 & 54;

nom. transl. H. & A. ADAMS, 1853: 167, *ex* Mitrinae; which is nom. correct. SWAINSON, 1840: 98-101, 112, 126, 129, 132, 154, *ex* Mitrianae (pls. 49 & 50), Mitranae (pls. 49, 50, & 54), & Mitriana (plt. 54)

= Mitrina GRAY, 1847: 141 (was a SF of Volutidae)

= Mitrolumnidae SACCO, 1904: 88, for *Mitrolumna*, which seems to be a member of the Mitrinae

= Peculatoridae IREDALE & McMICHAEL, 1962: 64, for *Peculator*, which seems to be a member of the Vexillinae

= Strigatellacea TROSCHER, 1869: 102, for *Strigatella*, which is a member of the Mitrinae (named as a family)

= Turritidae GRAY, 1857: 23, for *Turris* MONTFORT, which is a synonym of *Vexillum*, nominal genus of the Vexillinae

SF 1. Mitrinae SWAINSON, 1831: pls. 49, 50, & 54;

nom. correct. SWAINSON, 1840: 98-101, 112, 126, 129, 132, & 154, *ex* Mitrianae, Mitranae & Mitriana

= Diptychomitridae BELLARDI, 1889: 152, for *Dipty-*

- chomitra*, which seems to belong here  
 = "Orthomitridae" BELLARDI, 1888: 79 (unavailable, no nominal genus - ICZN Arts. 11e & 63). Originally included *Mitra* only.  
 = "Pseudomitridae" COSSMANN, 1899: 151 (no nominal genus). Originally included *Thala*, *Mutya*, & *Dibaphus*, of which the last two seem to belong here, the first in the Vexillinae  
 SF 2. Vexillinae THIELE, 1929: 337, for *Vexillum*  
 = "Plesiomitridae" BELLARDI, 1888: 277 (no nominal genus). Originally included *Uromitra*, *Turricula*, *Posia*, & *Micromitra*, which all seem to belong here  
 = "Semimitridae" COSSMANN, 1899: 151 (no nominal genus). Originally included *Conomitra*, *Mitrolumna*, & "*Ziervoglia*," of which the first and the last seem to belong here, the second to Mitridae  
 SF 3. Cylindromitridae COSSMANN, 1899: 152, for *Cylindromitra*, which has been replaced by *Pterygia*. The subfamily name is retained because of ICZN Art. 40.  
 SF 4. Imbricariinae TROSCHEL, 1867: 86, for *Imbricaria*; *nom. correct.* CERNOHORSKY, 1966: (this issue), *ex Imbricarina*

## II. GENUS-LEVEL NAMES

- Acuticylindra* IREDALE, 1929b: 287 [*\*A. nucea* "GRONOW, 1781: 298 (no. 1319)" [Work rej. ICZN Op. 261] = *Voluta nucea* GMELIN, 1791: 3449 (no. 43); M]  
*Aidone* H. & A. ADAMS, 1853: 172 [*\*A. insignis* (A. ADAMS) = *Mitra insignis* A. ADAMS, 1853: 132 (no. 4); M]. CERNOHORSKY (1966, this issue) suggests that this may be a member of the Columbellidae.  
*Arenimitra* IREDALE, 1929b: 286 [*\*A. arenosa* (LAMARCK) = *Mitra arenosa* LAMARCK, 1811: 219 (no. 68); OD = (*fide* CERNOHORSKY, 1966) *Voluta exasperata* GMELIN, 1791: 3453 (no. 135)]  
*Atrimitra* DALL, 1918: 138 [*\*Mitra idae* MELVILL, 1893: 140; OD]  
*Austromitra* FINLAY, 1927a: 410 & 477 [*\*Columbella* (*Atilia*) *rubiginosa* HUTTON, 1873: 20; OD = (*fide* COTTON, 1957: 6th p.) *Mitra analogica* REEVE, 1845: plt. 35 (no. 293)]  
*Balcomitra* FINLAY, 1927b: 508 [*\*Mitra paucicostata* TATE, 1889: 141 (no. 15); OD]  
 = *Baleomitra* NEAVE, 1939: 388 (*nom. null.*)  
*Callithea* SWAINSON, 1840: 130 & 320, *non* FEISTHAMEL, 1835, *ex* BOISDUVAL MS: plt. 122 [*\*Mitra sanguisuga* (LINNAEUS) = *Voluta sanguisuga* LINNAEUS, 1758: 732 (no. 364); SD HERRMANNSEN, 1846: 155] See *Pulchritima* IREDALE, 1929b  
*Cancilla* SWAINSON, 1840: 130 & 320 [*\*Mitra isabella* (SWAINSON) = *Tiara isabella* SWAINSON, 1831: plt. 50; SD HERRMANNSEN, 1846: 166]  
 = *Cancellia* GRAY, 1841: 142 (no. 96) (*nom. null.*)  
 = *Cancilia* HOERNES & AUINGER, 1880: plt. 9 (*nom. null.*)  
*Charitodoron* TOMLIN, 1932: 167 [*\*C. euphrosyne*; OD]. See BARNARD (1960: 402)  
*Chrysame* H. & A. ADAMS, 1853: 171 [*\*Mitra coronata* LAMARCK, 1811: 214-215 (no. 52); SD COX, 1927: 91]  
*Clifdenia* LAWS, 1932: 196 [*\*C. turneri*; OD]  
*Clinomitra* BELLARDI, 1889: 152 (p. 10 in reprint) [*\*C. rovasendae*; M]  
*Conoelix* SWAINSON, 1821: plt. 24 [*\*C. lineatus*; OD = *Mitra conularis* LAMARCK, 1811: 219 (no. 67)]. Genus = *Imbricaria* SCHUMACHER, 1817.  
 = *Conalex* PAETEL, 1875: 50 (*nom. null.*)  
 = *Conalix* JAY, 1836: 63 (*nom. null.*)  
 = *Conoehelix* SWAINSON, 1840: 127, 128, 129, & 132 (*nom. null.*)  
 = *Conohelix* SOWERBY, 1825: 79 (*nom. null.*)  
 = *Conolix* PAETEL, 1875: 53 (*nom. null.*)  
*Conomitra* CONRAD, 1865: 25 [*\*Mitra fusoides* LEA, 1833: 169; SD FISCHER, 1884: 613]  
*Costellaria* SWAINSON, 1840: 130 & 320 [*\*C. rigida* (SWAINSON) = *Mitra rigida* SWAINSON, 1821: plt. 29; M = (*fide* CERNOHORSKY, 1966) *Mitra semifasciata* LAMARCK, 1811: 217 (no. 60)]  
*Cucurbita* SCUDDER, 1882: 93, *ex* MEGERLE MS (in synon. with *Mitra*)  
*Cylindra* SCHUMACHER, 1817: 71 & 236 (no. 91), *non* ILLIGER, 1802: 303 (which is a *nom. van.*) [*\*C. coronata* = *Voluta crenulata* GMELIN, 1791: 3452 (no. 130); M] See *Cylindromitra* FISCHER, 1884.  
 = *Cylinder* MELVILL & STANDEN, 1895: 103 (*nom. null.*), *non* MONTFORT, 1810: 390  
*Cylindromitra* FISCHER, 1884: 614, *nom. nov. pro* *Cylindra* SCHUMACHER, 1817, "*non* *Cylinder* MONTFORT, 1810: 390," actually *non* ILLIGER, 1802. Genus = *Pterygia* RÖDING, 1798  
 = (?) *Cylindrina* RISBEC, 1955: 72 (*nom. null.*)  
*Dactylus*, *auctt.*, as IREDALE, 1929b, *non* SCHUMACHER, 1817: 70 & 234 (genus 86). Genus = *Pterygia* RÖDING, 1798.  
*Dibaphus* PHILIPPI, 1847: 61 & 63 [*\*Conus edentulus* REEVE, 1844: plt. 11 (no. 80), *ex* SWAINSON MS; M]  
*Diplomitra* FINLAY, 1927a: 408 & 477 [*\*Cymbiola nitens* MARSHALL, 1918: 266; OD]  
*Diptychomitra* BELLARDI, 1889: 152-155 (pp. 10-13 in

- reprint) [*D. eximia*; SD herein (first on list of 7)]. Is a member of the Columbelloidea, *vide* CERNOHORSKY, 1966. It seems rather to belong here.
- Ebenomitra* MONTEROSATO, 1917: 26 [*\*Mitra ebenus* LAMARCK, 1811: 216-217 (no. 58); SD herein (second on list of 2)]
- Egestas* FINLAY, 1927a: 411 [*\*Vexillum waitei* SUTER, 1909: 124-125; OD]. Tentatively assigned to the Mitridae on the advice of Dr. R. Batten of the American Museum of Natural History.
- Episcomitra* MONTEROSATO, 1917: 26 [*\*Mitra zonata* "SWAINSON" = *Mitra zonata* MARRYAT, 1819: 338; M]
- Eumitra* TATE, 1889: 135 (proposed *Eu-Mitra*<sup>1</sup>) [*\*Mitra alokiza* TENISON-WOODS, 1879: 9; SD LUDBROOK, 1958: 71]
- Eumitra* MELVILL & STANDEN, 1895: 99-100, non TATE, 1889: 135 [*\*Mitra (E.) episcopalis* LINNAEUS, 1758: 732 (no. 368); SD herein (second on list of 3)]. Genus then = *Mitra* LAMARCK, 1798.
- Fuscomitra* PALLARY, 1900, ex MONTEROSATO MS: 263 [*\*Mitra (F.) fusca* (SWAINSON) = *Mitra fusca* SWAINSON, 1824: 35-36; SD WENZ, 1943: 1292 (no. 3683)]
- Fusimitra* CONRAD, 1855: 261 [*\*Mitra mellingtoni*; SD GRANT & GALE, 1931: 636]
- Idiochila* PILSBRY, 1921: 311 [*\*Vexillum turben* (REEVE) = *Mitra turben* REEVE, 1844: plt. 27 (no. 213); OD]
- Imbricaria* SCHUMACHER, 1817: 71 & 236; plt. 21 (no. 90) [*\*I. conica* = *Voluta decorata* LIGHTFOOT, 1786: 27 (no. 640) (*nom. nud.*); M = *Mitra conularis* LAMARCK, 1811: 219 (no. 67)]
- Isara* H. & A. ADAMS, 1853: 171 [*\*Mitra bulimoides* REEVE, 1845: plt. 28 (no. 224); SD COSSMANN, 1899: 153]
- Latiromitra* LOCARD, 1897: 321 [*\*L. specialis*; M]
- Mauritia* H. ADAMS, 1869: 273 & 275, non TROSCHEL, 1863: 205, 208 & 209; plt. 67 [*\*M. barclayi*; M]
- Mesorhytis* MEEK, 1876: 356 & 364 [*\*Fasciolaria (M.) gracilentia*; M]
- Micromitra* BELLARDI, 1889: 147-151 (pp. 5-9 in reprint), non MEEK, 1873: 479 [*\*M. taurina*; SD herein (first on list of 9)]
- Mitra* LAMARCK, 1798, ex MARTYN MS: pls. 369-377 (genus without species - ICZN Art. 69 a (ii)). Original list provided by RÖDING, 1798: 135-138<sup>2</sup>. [*\*Voluta episcopalis* LINNAEUS, 1758: 732 (no. 368); SD MONTFORT, 1810: 543]. Species name ICZN pending (See COAN, 1966).
- = *Mitraria* RAFINESQUE, 1815 (*nom. subst.*) [*\*Voluta episcopalis* LINNAEUS, 1758: 732 (no. 368); Art. 67i]
- = *Mitraxia* BINNEY & TRYON, 1864: 19 (*nom. null.*)
- = *Mitrolithes* KRÜGER, 1823: 431 (unavailable: ICZN Art. 20, also *nom. nud.*)
- = *Mytra* LAMARCK, 1811: 212 (no. 44) (*nom. null.*)
- Mitra*, auctt., non RÖDING, 1798 = *Scabricola* SWAINSON, 1840
- Mitrella* SWAINSON, 1831: plt. 54, non RISSO, 1826: 247 [*\*Mitra fissurata* LAMARCK, 1811: 209-210 (no. 34); SD COSSMANN, 1899: 152 (spelled "*fissuella*" & "*fissurella*" by SWAINSON)]. See *Swainsonia* H. & A. ADAMS, 1853.
- Mitreola* SWAINSON, 1833: plt. 128 [*\*Mitra monodonta* LAMARCK, 1803: 58 (no. 2); SD HERRMANNSEN, 1847: 45]
- Mitridomus* SOHL, 1963: 749 [*\*Fasciolaria ripleyana*
- <sup>2</sup> The authorship of the genus *Mitra* is an important question about which there is disagreement among workers. The decision as to whether to credit the genus to LAMARCK (1798) or to RÖDING (1798) depends on the dating of these works. The facts seem to be as follows:
- (a) The section of the "Tableau encyclopédique . . ." (BRUGUIÈRE, LAMARCK & BORY DE SAINT-VINCENT, 1791-1827) containing the plates on *Mitra* were completed by LAMARCK and are generally thought to have been published prior to 22 September 1798. The evidence for this is discussed by REHDER (1944) and MACNEIL (1960).
- (b) The Introduction to RÖDING (1798) by LICHTENSTEIN is dated 10 September 1798 (p. vi).
- (c) REHDER (1944) and MACNEIL (1960) give reason to believe that RÖDING (1798) could not have been published until November or December, 1798, possibly even as late as January, 1799.
- CERNOHORSKY (1966 & in litt.) believes that REHDER's evidence is insufficient to demonstrate that RÖDING was published any later than 10 September, the date of LICHTENSTEIN's Introduction, and that the genus *Mitra* dates from RÖDING (1798). I, on the other hand, believe that RÖDING (1798) must be dated from 31 December 1798, because the date of an Introduction cannot be taken as a date of publication (ICZN Art. 21 b-ii applies). As evidence of the last point I would cite the 1961 edition of the *International Code of Zoological Nomenclature* itself. The Introduction of this edition is dated 16 January 1961, whereas the volume was actually issued on 6 November 1961.
- This question should probably be settled by the International Commission on Zoological Nomenclature. However, since several other generic names may be involved, additional research into this matter would have to be done. This should probably be undertaken by a worker in Europe who might have access to correspondence.

<sup>1</sup> I doubt whether TATE's name, originally published as "*Eu-Mitra*," was intended to represent anything more than *Mitra s.s.* However, in view of the fact that LUDBROOK (1958) has selected a type from among the list of species that TATE (1889) included in his category, I will accept the name. I know of no precedent for this. *Eumitra* MELVILL & STANDEN (1895), on the other hand, was used to indicate *Mitra s.s.* and was more properly proposed. It is, of course, preoccupied by TATE's name. I have designated *Voluta episcopalis* LINNAEUS, 1758, as type, so as to eliminate it from consideration.

- WADE, 1926: 133; OD]
- Mitroidea* PEASE, 1865: 514 [\**M. multiplicata*; M]
- Mitrolumna* BUCQUOY, DAUTZENBERG & DOLLFUS, 1883: 121 [\**Mitra olivoidea* CANTRAINE, 1835: 391; OD]. Is a member of the Turridae *fide* CERNOHORSKY, 1966. POWELL (1942: 17) suggests the Mitridae.
- = *Mitrolumma* MARTENS, 1884: 42 (nom. null.)
- Mitromica* BERRY, 1958: 94 [\**Mitra solitaria* C. B. ADAMS, 1852: 268; OD]
- Mitropifex* IREDALE, 1929a: 346 [\**M. quasillus*; M]
- Mutyca* H. & A. ADAMS, 1853: 172 [\**Dibaphus* (M.) "ancilloides" (SWAINSON) = *Mitra ancillides* BRODERIP, 1836: 193; SD WENZ, 1943: 1296 (no. 3694)]
- Nebularia* SWAINSON, 1840: 130, 131, & 319 [\**Mitra contracta* SWAINSON, 1820: plt. 18; SD HERRMANNSEN, 1847: 110 = *Voluta abbatis* DILLWYN, 1817: 557 (no. 140), *ex* CHEMNITZ MS, *non* PERRY, 1811: plt. 39]
- Neomibricaria* IHERING, 1907: 67 & 198-200 [\**Voluta patagonica* IHERING, 1897: 306-307; SD COSSMANN, 1909: 219]
- Paleofusimitra* SOHL, 1963: 750 [\**P. elongata*; OD]
- Papalaria* DALL, 1915: 60 (genus without species) [\**Voluta episcopalis* LINNAEUS, 1758: 732 (no. 368); SD hercin]. Genus then = *Mitra* LAMARCK, 1798.
- Parvimitra* FINLAY, 1930: 63-64; plt. 3 [\**P. pukeuriensis*; OD]
- Peculator* IREDALE, 1924: 183, 269, & 270 [\**P. verconis*; M]
- Phaeomitra* MARTENS, 1880: 252 [\**Mitra* (P.) *fulva* SWAINSON, 1829: plt. 30 = (*fide* CERNOHORSKY, 1966) *Mitra coffea* SCHUBERT & WAGNER, 1829: 83; SD herein (first on list of 6)]
- Pleioptygma* CONRAD, 1863: 563 [\**P. (Mitra) carolinensis* (CONRAD) = *Voluta carolinensis* CONRAD, 1840: 387; M]
- = *Pleioptygma* COSSMANN, 1899: 150 & 160-162 (nom. van.)
- Plochelaea* GABB, 1873: 271-272 [\**P. crassilabra*; OD]
- Proximitra* FINLAY, 1927a: 410 & 477 [\**Vexillum rutidolomum* SUTER, 1917: 29; OD]
- = *Proximitra* ALLAN, 1927: 291 (1st. rev. NEAVE, 1940: 949)
- Pseudocancilla* STAADT in COSSMANN, 1913: 194; plt. 3 [\**Mitra* (P.) *restifera*; OD]
- Pterygia* RÖDING, 1798: 51 [\**P. nucella* = *Voluta dactylus* LINNAEUS, 1767: 1188 (no. 401); SD DALL, 1915: 52]
- = *Pterigia* BUCQUOY, DAUTZENBERG & DOLLFUS, 1882: 71 (nom. null.)
- Pulchritima* IREDALE, 1929b: 286, nom. nov. *pro Callithea* SWAINSON (preocc.)
- Pusia* SWAINSON, 1840: 320 [\**P. "microzonis"* (LAMARCK) = *Mitra microzonias* LAMARCK, 1811: 218 (no. 62); M = (*fide* CERNOHORSKY, 1965) *Voluta sulcata* GMELIN, 1791: 3455 (no. 69), *non* GMELIN, 1791: 3436 (no. 3)]. For a discussion of the last two species, see KEEN (1958: 623-624)
- = *Pusio* TATE, 1889: 136 (nom. null.)
- Pusiola* MONTEROSATO, 1917: 26, *non* WALLENGREN, 1863: 146-147 [\**P. tricolor* (GMELIN) = *Voluta tricolor* GMELIN, 1791: 3456 (no. 76); M]
- Pusiolina* COSSMANN, 1921: 79, nom. nov. *pro Pusiola* MONTEROSATO (preocc.)
- Scabricola* SWAINSON, 1840: 130, 131, & 319 [\**Mitra serpentina* LAMARCK, 1811: 204 (no. 21); SD GRAY, 1847: 141 (no. 94) as "*Scabricola*" = (*fide* CERNOHORSKY, 1966) *Voluta variegata* GMELIN, 1791: 3457 (no. 89)]
- = *Scabricola* GRAY, 1847: 141 (no. 94) & 217 (nom. null.)
- = *Scabricula* SOWERBY, 1842: 251 (nom. null.)
- Strigatella* SWAINSON, 1840: 130, 131, & 319 [\**Mitra zebra* LAMARCK, 1811: 215 (no. 53); SD GRAY, 1847: 141 (no. 94) = (*fide* DODGE, 1955) *Voluta paupercula* LINNAEUS, 1758: 731 (no. 359)]
- Subcancilla* OLSSON & HARBISON, 1953: 190 [\**Mitra sulcata* SWAINSON in SOWERBY, 1825: pp. xxvi-xxvii (no. 2095); OD]. See KEEN (1958: 623-624) concerning this specific name.
- Swainsonia* H. & A. ADAMS, 1853: 180, nom. nov. *pro Mitrella* SWAINSON (preocc.)
- Thala* H. & A. ADAMS, 1853: 178 [\**Mitra mirifica* REEVE, 1845: plt. 34 (no. 278); SD COSSMANN, 1899: 176]
- Tiara* SWAINSON, 1831: plt. 50 [\**Mitra corrugata* LAMARCK, 1811: 205-206 (no. 24); SD GRAY, 1847: 142 (no. 96)]
- = *Thiara* SWAINSON, 1840: 130 (nom. null.)
- Tiara*, *auctt.*, *non* SWAINSON, 1831: plt. 50 = *Cancilla* SWAINSON, 1840
- Tiarella* SWAINSON, 1840: 130 & 131 [\**Voluta papalis* LINNAEUS, 1758: 732 (no. 369); SD GRAY, 1847: 141 (no. 94). Genus = *Mitra* LAMARCK 1798.
- = *Thiarella* SWAINSON, 1840: 319 (1st. rev. HERRMANNSEN, 1847: 576)
- Tosapusia* AZUMA, 1965: 55-56 [\**Mitropifex isaoi* KURODA & SAKURAI in KURODA, 1959: 324-326; OD] (see also KURODA, 1958)
- Turricula* COSSMANN, 1899: 162, *ex* KLEIN MS, *non* SCHUMACHER, 1817: 66 & 217 (no. 63), & *non* FABRICIUS, 1823: 80 [\**Mitra vulpecula* LINNAEUS, 1758: 732 (no. 365); OD] = *Vexillum* RÖDING, 1798.
- Turricula* FABRICIUS, 1823: 80, *non* SCUMACHER, 1817: 66 & 217 (no. 63) [\**T. plicaria* = *Voluta plicaria* LINNAEUS, 1758: 732 (no. 366); SD herein (first on list

- of 13)], = *Vexillum* RÖDING, 1798
- Turris* MONTFORT, 1810: 538-539, *non* RÖDING, 1798: 123 [\**T. vulpecula* (LINNAEUS) = *Voluta vulpecula* LINNAEUS, 1758: 732 (no. 365); OD]. = *Vexillum* RÖDING, 1798.
- Uromitra* BELLARDI, 1888: 277-280 (pp. 23-26 in reprint) [\**Mitra cupressina* (BROCCHI) = *Voluta cupressina* BROCCHI, 1814: 319 (no. 21); SD COSSMANN, 1899: 168]
- Vexillitra* MARWICK, 1931: 124-125 [\**V. balteata*; OD]
- Vexillum* RÖDING, 1798: 138 [\**V. plicatum* = *Voluta plicaria* LINNAEUS, 1758: 732 (no. 366); SD WOODRING, 1928: 244]
- Vicimitra* IREDALE, 1929 a: 343 [\**V. prosphora*; M]
- Volvaria* LAMARCK, 1801: 93 [\**V. bulloides*; M]  
= *Volvarius* MONTFORT, 1810: 410-411 (*nom. van.*)
- Volvariella* FISCHER, 1883: 553 [\**V. "lamarcki"* (DESHAYES) = *Mitra lamarckii* DESHAYES, 1832: 448 (no. 1); M]
- Vulpecula* BLAINVILLE, 1824: 106-108, *non* JAROCKI, 1822: 454 [\**Voluta vulpecula* LINNAEUS, 1758: 732 (no. 365); T] Genus = *Vexillum* RÖDING, 1798.
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= *Waimatea* ALLAN, 1927: 289, 291, & 292 (1st. rev. NEAVE, 1940: 650)
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# Additions to the Molluscan Fauna of Clipperton Island

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MOLLUSKS COLLECTED by the junior author and his colleagues during two cruises of the Scripps Institution of Oceanography Research Vessel *Spencer F. Baird* to Clipperton Island (1956 and 1958) have been reported in preliminary form in three previous notes in *The Veliger* (ALLISON, 1959; HERTLEIN & ALLISON, 1960 a; HERTLEIN & ALLISON, 1960 b). Species identified in the collections of earlier expeditions and a review of pertinent literature concerning that island are discussed by the senior author in collaboration with William K. Emerson (HERTLEIN & EMERSON, 1958). More comprehensive discussions of Clipperton Island natural history appear in the works of SACHET (1960, 1962 a, 1962 b, 1962 c, 1963). The species reported in the present paper represent all other mollusks recognized in currently available Clipperton Island collections, including those recently dredged from the *Baird* during the expedition CARROUSEL (11 August, 1964).

The unique combination of Eastern Pacific and Indo-Pacific elements in the Clipperton Island biota has required the aid of authorities and collections other than those immediately available to the authors. We gratefully acknowledge aid received from Dr. E. Alison Kay, General Science Department, University of Hawaii, who generously gave of her time to check the identifications of several specimens with similar ones in the Bernice P. Bishop Museum. Dr. A. Myra Keen, Department of Geology, Stanford University, furnished information concerning the vermetid forms in Clipperton Island collections; Dr. Ruth Turner, Museum of Comparative Zoology, Harvard University, furnished identifications of species of *Lithophaga* and *Martesia*; and Dr. Hendryk Stenzel, Shell Development Corporation, Houston, Texas, contributed useful comments concerning the species of *Ostrea*; as did A. G. Smith, California Academy of Sciences, concerning the species of *Ischnochiton*.

## PELECYPODA

### ARCIDAE

#### *Arca mutabilis* (SOWERBY, 1833)

One left valve from beach drift; 23 mm long; one juvenile valve comparable to this species was dredged at depth of 92 m off southeastern side of island.

#### *Barbatia reeveana* (D'ORBIGNY, 1846)

One specimen, 24.4 mm long, from beach drift.

#### *Barbatia reeveana* (D'ORBIGNY, 1846) (form *velataformis* SHELDON & MAURY, 1922)

Two somewhat worn valves, both about 41 mm long, from beach drift.

#### *Acar* cf. *A. laysana* DALL, BARTSCH & REHDER, 1938

One small specimen, about 5 mm long, found living in live colony of coral *Pocillopora* at about 15 m depth on north side of island.

### MYTILIDAE

#### *Lithophaga hancocki* SOOT-RYEN, 1955

Living in coral along outer edge of "10 fathom" terrace (depth 10 to 16 m).

#### *Lithophaga plumula* HANLEY, 1843

Commonly living in coral rock along outer part of reef flat.

#### *Lithophaga* (*Stumpiella*) *calyculata* (CARPENTER, 1856)

One well preserved specimen dredged at depth of 92 m off southeastern side of island.

### PINNIDAE

#### *Pinna* species

Dead specimens seen *in situ* in sediment patches in lagoon at depth of 8 to 10 m.

## PTERIDAE

*Pinctada mazatlanica* (HANLEY, 1856)

Living specimens immediately below outer edge of "10 fathom terrace," at depths of 30 to 35 m, on north side of island; dead specimens with ligament in place collected in 1958 on northern portion of island surface which was then strewn with shells and coral debris deposited by recent storm waves; dead specimens in lagoon and on beaches of island.

## ISOGNOMONIDAE

*Isoognomon chemnitzianum* (D'ORBIGNY, 1853)

Dead valves from beach.

*Isoognomon janus* CARPENTER, 1856

Living specimens commonly attached to dead coral blocks on reef flat; dead specimens on beaches around island.

## SPONDYLIDAE

*Spondylus gloriosus* DALL, BARTSCH & REHDER, 1938

Living near outer edge of "10 fathom terrace" at depths greater than 15 m and observed downward to about 45 m, the maximum depth reached during collecting dives; robust dead specimens occur commonly in coarse coral debris of beaches around island; specimens with delicate spines occur with fossil coral reef assemblages of shallow areas in lagoon.

Figures of specimens apparently identical with those from Clipperton Island appear in *Hawaiian Shell News* (Vol. 11, no. 5, new ser., no. 39, p. 1, figs. 1, 2) for March, 1963. The Hawaiian specimens were collected by SCUBA divers off Maui.

## OSTREIDAE

*Ostrea hyotis* LINNAEUS, 1758

Small specimens commonly living off shore near limit of deepest dives (40 to 45 m); large specimens found living only off outer edge of "10 fathom terrace;" large dead specimens found *in situ* among fossil coral reefs of lagoon, commonly at depths greater than 10 m below present water level of lagoon; isolated dead valves on beach but large examples common only among fresh debris deposited on north side of island by storm waves preceding 1958 expedition.

## LUCINIDAE

*Codakia distinguenda* (TRYON, 1872)

Several valves, reaching a maximum length of 91 mm, from fossil assemblages in lagoon and from beach drift around perimeter of island.

*Codakia thaenumi* PILSBRY, 1918

Valves, up to 64 mm long, common in sediment (containing fossils) in lagoon.

*Ctena clippertonensis* BARTSCH & REHDER, 1939

Living among sand and dead coral debris on reef flat and off shore to depths of about 15 m; largest specimen 15.6 mm long.

## CHAMIDAE

*Chama squamuligera rubropicta* BARTSCH & REHDER, 1939

Numerous isolated valves mostly about 16 mm long, from beach drift around island; living specimens from below "10 fathom terrace" to depths of deepest dives (40 to 45 m); one eroded lower valve attached to coral with specimen of *Codakia thaenumi* which evidently came from lagoon; several valves dredged at a depth of 92 m off southeastern side of island.

## GASTROCHAENIDAE

*Gastrochaena (Rocellaria) ovata* SOWERBY, 1834

A number of living specimens were dredged at a depth of 92 m off southeastern side of island.

## PHOLADIDAE

*Martesia striata* (LINNAEUS, 1758)

Dead specimens with valves together from coral debris at depth of 10 to 12 m off north side of island; valves common in beach debris.

## GASTROPODA

## FISSURELLIDAE

*Diodora granifera* (PEASE, 1861)

Commonly living under boulders on reef flat areas strewn with loose blocks of dead coral but free from exposed sand, particularly evident near middle of reef flat on north side of island; dead shells rare on beaches; juvenile shell, probably referable to this species, dredged at depth of 92 m off southeastern side of island.

## CYCLOSTREMATIDAE

*Cyclostrema cingulifera* A. ADAMS, 1850

Commonly living in protection of algae and tubeworms on outer edge of reef flat.

## EULIMIDAE

*Balcis* cf. *B. cumingi medipacifica* (PILSBRY, 1917)

Dead shell from reef flat on south side of island.

*Balcis thaenumi* (PILSBRY, 1917)

Common among boulders in reef flat tide pools on west side of island; none living, but many shells occupied by hermit crabs.

*Balcis vafra* (PILSBRY, 1917)

Dead specimen from tide pool near shore, on west side of island.

## ARCHITECTONICIDAE

*Heliacus infundibulum strigata* (HANLEY, 1863)

One dead specimen from beach drift on northeast side of island.

## VERMETIDAE

*Petalconchus (Macrophragma)* species

Dead shells in beach drift.

*Spirogyphus* cf. *S. platypus* (MÖRCH, 1861)

Dead shells in beach drift.

## CERITHIIDAE

*Cerithium nesioticum* PILSBRY & VANATTA, 1906

Dead shells from beach drift on all sides of island; particularly common (dead) in tide pools on west side of island.

## COLUBRARIIDAE

*Colubraria* species

No living specimens found; dead shells fairly common in beach drift and in tide pools on west side of island; specimens occupied by hermit crabs found on north side of island at depths from 10 to 15 m.

## MURICIDAE

*Ocenebra* cf. *O. vittata* (BRODERIP, 1833)

Juvenile specimen comparable to BRODERIP's species dredged at depth of 92 m off southeastern side of island.

## GALEODIDAE [VOLEMIDAE]

*Pugilina lactea* (REEVE, 1847)

A single specimen in the University of California Museum of Paleontology collection, with the locality "No. 7191, Clipperton Island." It agrees well with REEVE's illustration of *Pyrula lactea* REEVE which was originally described from the Philippine Islands. No examples or fragments were recovered during recent expeditions to Clipperton Island. Confirmation of this record of occurrence is desirable.

## FASCIOLARIIDAE

*Fasciolaria princeps* SOWERBY, 1825

One dead specimen from beach drift on west side of island.

*Latirus* aff. *L. socorroensis* HERTLEIN & STRONG, 1951

Represented by a single dead specimen from beach drift on northwestern side of island; sculpture more rugose than on the typical form.

*Peristernia thaunumi* PILSBRY & BRYAN, 1918

Living specimens collected from north side of island near outer edge of "10 fathom terrace," at depths of

from 10 to 20 m; dead specimens common in beach drift of north and west sides of island.

## ACHATINIDAE

*Opeas oparanum* (PFEIFFER, 1846)

Living commonly in protection of rock and plant debris on island.

## AMPHINEURA

## ISCHNOCHITONIDAE

*Ischnochiton* species

Specimens of small, as yet unidentified, *Ischnochiton* from beneath boulders on outer part of reef flat along north side of island.

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## On Some Taxonomic Categories which have been Proposed for the Classification of Large Gastropod Genera

BY

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IN A RECENT ISSUE of this journal, SCHILDER (1966) gave some "Personal Views on Taxonomy" in relation to classification at the generic, and lower, levels. It was suggested by the editor that the *Veliger* could provide a forum for the discussion of these ideas, without passing judgment. I am, therefore, pleased to present a contrary point of view. The opinions expressed here are my own, and are not necessarily endorsed by the editors; moreover, I do not claim to have originated them, for the taxonomic principles at issue are discussed by SIMPSON (1961) and others. Yet it does seem reasonable to re-emphasize these points, in view of the practices of many malacologists.

The issue at hand has been characterized as a difference in taste between "splitters" and "lumpers" (SCHILDER, 1963). But the basic problem is somewhat more involved; indeed, it is highly technical. The fundamental principles of taxonomy include some strictly logical features which cannot be left out of consideration in practical systematics; it is these which shall be discussed here.

Among the basic concepts which have been elaborated in taxonomic theory is the distinction between *taxa* and *categories*. A *taxon* is a group of animals; *Cypraea* is a taxon. A *category* is a level in a system of classification; the genus is a category. SCHILDER (1966) maintains older usage by not distinguishing between the two. The introduction of the distinction makes it easier to avoid a number of mistakes, particularly with respect to problems of definition. It is one thing to define the name of a category, such as "species," another to define the name of a particular taxon, such as "Gastropoda" (GHISELIN, Systematic Zoology, in press). Modern biology (*e.g.* MAYR, 1963) generally uses the word "species" to designate populations of organisms which are reproductively isolated from other such groups. Thus, two organisms, by definition, belong to different species if it is impossible, under natural conditions, for them or their descendants to interbreed. This is what is meant when a biologist, rightly

or wrongly, says that all men constitute a single species. Yet as all working systematists are abundantly aware, it is in practice difficult to tell what is, or is not, by definition a species. Therefore, indirect evidence, such as distribution and anatomical structure, is used to erect tentative classifications until definitive evidence is available. SCHILDER (1966, p. 183) would seem to agree on these points. Yet it is very misleading when he calls a morphological test a "definition": "groups of similar shells should be treated as different species if they can be separated by at least one well recognizable character showing no intermediates even in extreme specimens." To call this criterion a definition implies that should evidence be brought forth which demonstrates that a given grouping of organisms does exchange, or can exchange, genes with another such grouping, they would still belong to different species. Thus, by definition, one would have to subdivide the species which includes domestic dogs into at least two species, including one for basset hounds, as these show no intermediates in their short-leggedness.

The objection to using a morphological species definition is that it seems desirable to have the classification-system correspond to an order having real existence in nature. Whether or not we happen to be able to separate specimens into groups has no bearing upon what the animals are doing in nature. It is for this reason that, in order to insure nomenclatural precision, the names of a species are defined ostensively<sup>1</sup>, by reference to a type specimen. That is to say, a species name applies to those organisms which belong to the same species as the type specimen. The definition being ostensive, the characters, morphological or otherwise, are not defining of the name, even though they may be useful evidence.

<sup>1</sup> An "ostensive definition" is one in which the meaning of the word is given by stating the word and showing the thing: a christening is an ostensive definition.

The criterion of reality of taxa (*not* categories) is met upon the higher levels by having the taxa correspond, approximately, to groups delineated on the basis of their genealogical affinities; i. e., the most closely related forms are grouped closest together. At the species level, the names of taxa designate reproductively-isolated populations. At lower levels, the problem is somewhat more difficult, but in general, species are divided into subspecies on a basis analogous to the division of genera into species; subspecies are populations, but their reproductive isolation is only partial.

The manner in which organisms are classified is partly determined by the way in which groupings are organized into a unitary system. Organisms are placed into a system of classes forming the *Linnean hierarchy*, a kind of organization which has a very definite structure. As a consequence of this structure, there are certain limitations upon the manner in which groupings may be subdivided. For instance, the taxa are assigned particular *categorical ranks*: e. g., Mollusca has the rank of a phylum. The question of the precise categorical rank of a taxon (for example, whether *Cypraea* should be a genus or a family) is to some measure subject to the personal choice of systematists. However, if different criteria of rank are used in different taxa, the system becomes less informative. Further, the decision as to what rank to give a taxon is generally dependent, not only upon the relationships of the organisms, but in addition upon the degree of modification which the organisms have undergone. Thus, on the basis of their relationships, birds could easily be made a subclass of reptiles, but as they have become greatly altered, they are given a higher categorical rank and made a class.

The possible number of categories is not limited by the structure of the Linnean hierarchy. Therefore, there can be no logical objection to SCHILDER's proposal to increase the number of categories below, or just above, the species level. In large genera which show distinct, but closely-related and little-modified subgroupings, the erection of subgenera is quite desirable. However, to raise the categorical rank of a taxon, for instance to make a subgenus a genus, simply because the group is a large one, loses sight of one meaning of categorical rank. Genera should, in so far as it is feasible, correspond to a comparable degree of difference throughout the system. Otherwise the system will not convey the amount of information about the organisms which it is able to express. Hence the opinion of KAY (1960) that the genus *Cypraea* should not be subdivided into several taxa of generic rank is in accord with the logical foundations of taxonomy.

Again, there is no logical objection to having several categories upon the infraspecific level. Minor and major

differences, as SCHILDER (1966) suggests, could be distinguished on the basis of respectively lower, or higher, categorical rank. I shall omit, from this discussion, the problem of whether or not such a procedure is practical or useful; SIMPSON (1961), however, treats it adequately.

Further properties of the Linnean hierarchy impose limitations upon how animals may be classified. For instance, the groupings must be set up so that organisms are not placed in two taxa of the same rank; i. e., a shell must be either a *Cypraea* or a *Murex*, not both. Similarly, in so far as rules are adopted for assigning a particular rank to a taxon, the rules should be applied consistently throughout the group. What this means will be brought out by examples to follow.

SCHILDER (1966) suggests that sexual forms must not be named. It is curious that he calls them "taxa," although it is not impossible, in an artificial system, to treat them as such. The logical reason for not putting males and females in different taxa is that it confuses the meaning of categorical rank. If, say, *Cypraea* were divided into two groups, males and females, with a rank of subgenus, then every species of *Cypraea* would have to be broken up into two species, each of which consisted of individuals having the same sex, and no specific name could designate groupings of organisms which were not all males or all females. Such a classification system would be utter nonsense in terms of biology. Therefore, the only way to prevent confusion, and still be able to name classes of sexual forms, would be to make the division on this basis at the lowest categorical level.

Now SCHILDER (1966) does not explain the logical objections to attaching names to classes of males and females, nor does he explain why he objects to naming classes of juveniles or of monstrosities. The reasons are, of course, analogous to those for not giving males and females different names; it would play havoc with the hierarchy. He even goes so far as to suggest (SCHILDER, 1966, unnumbered figure) that all the taxa which "must not be named" are all single individuals. This does not fit in with the conventional distinction between a class and an individual. The name of a taxon may designate a class of organisms. Classes need not have members, in which case they are *null classes* (e. g., men over 25 feet tall). However, if a name is to refer to something, it must designate an individual or a class of individuals. If the name is of an individual, such as John Smith, it is a *proper name*. If the name is of a class, such as blue books, it is a *class name*. In taxonomy, the names are proper nouns or class-names according to the manner of definition. Thus if the category "species" by definition means that all species are biological populations, the names of the species are proper



nouns, and the species themselves are, in a sense, individuals. *Homo sapiens* LINNAEUS is an individual population. However, there is no logical objection to treating taxa as class names and to defining the names of taxa as classes of individuals. Now it would be absurd to assert that those categories which SCHILDER groups as formae, such as the "forma sexualis," refer to class-names for individuals. Clearly, "male cowries" and "female cowries" likewise refer to classes of organisms and are not in any way conceivable as names for single individuals. The distinctive feature of such categories is not that the names are of single individuals but rather that the names in no sense are, like species names, proper nouns.

The real issue at hand may be elucidated by a hypothetical example. Suppose that we did allow the naming of two of the kinds of taxa which SCHILDER says, and I think rightly, must not be named. We might try to name both sexual formae and monstrosities. But should we make the monstrosity or the forma sexualis the higher category? Or, in other words, which of the following are we to prefer:

```

genus
  species
    forma sexualis
      monstrosity, or,
genus
  species
    monstrosity
      forma sexualis ?

```

In terms of taxa, this would mean a choice like the following:

```

males
  "type A" (male) monsters
  "type B" (male) monsters
females
  "type A" (female) monsters
  "type B" (female) monsters; or
"type A" monsters
  male ("type A") monsters
  female ("type A") monsters
"type B" monsters
  male ("type B") monsters
  female ("type B") monsters.

```

All these groupings could, in theory, be used to classify shells. But we see that any decision to divide upon one basis before the other is wholly arbitrary and leads to biologically meaningless classifications. In nature, monsters do not separate into units composed of only males and

only females. Nor do monsters occur as sub-units of sexual populations.

Now there is no evident difference of opinion between SCHILDER and myself, as to the folly of naming classes of sexual formae and the like. Yet there are certain analogous infraspecific taxa which he says (SCHILDER, 1966) "must" or "may" be named. I shall discuss these in his sequence of presentation.

**Clines.** SCHILDER says that "Clines differ from true subspecies by the far more gradual passing of adjacent taxa into each other, so that only specimens coming from opposite extremes of the inhabited areas show typical characters, while the large area between these extremes contains populations of intermediate or of mixed extremes . . . ." As SIMPSON (1961) and others have pointed out, the cline is not a taxonomic concept; that is to say, clines are not groups of organisms. A cline is a geographical gradation of characters. As a variety of characters may display different patterns of variation in the same taxon, it follows that the same organism may be a part of several different clines. Clines cannot coherently be assigned any definite categorical rank; species, subspecies, even local populations may display clinal variation, and even the most trivial differences may constitute such variation. The attempt to name clines, therefore, would be like trying to divide the class of Americans into males, females and Californians.

**Morphes.** SCHILDER (1966, p. 185) asserts that "morphes evidently are highly stable mutants." I can see no difference between naming sexual forms and naming morphes. For a morphe is nothing more than a class differentiated upon the basis of characters which do not intergrade, irrespective of whether or not the individuals interact, in nature, as a unit. People are, or are not, achondroplastic dwarfs, and there are no intergrades, but no taxon is erected for them. Evidently, SCHILDER has not distinguished between artificial classes of mutant individuals, and natural populations in which the individuals are mutants. The failure to make this distinction leads him into a manifest self-contradiction, when he asserts that morphes are highly-stable mutants. For in referring to a morphe as a mutant, he can only mean that the individuals which make up each morphe are mutants, for a class cannot mutate. Yet when he says that morphes are stable, he can only refer to the historical nature of the class. It seems inescapable that SCHILDER has derived much of his conception of taxonomic groupings from an elementary logical fallacy, namely, confounding classes with individuals.

**Aberrations.** SCHILDER (1966, p. 186) defines this category thus: "Aberrations are populations the members of which have been influenced by certain special condi-

tions of their habitat; they will be found in scattered places with similar environments." Evidently, the individuals which make up these groupings are analogous to the ecotypic variations of conventional biology. But he seems not to realize that classes of aberrant individuals do not necessarily constitute biological populations. The difficulty of incorporating the aberration into biological classification is that a single organism may be referred to more than one class of aberrations, and that these may overlap with taxa of various categorical ranks. Thus it is possible for a species to consist of several subspecies, each of which has members which display the same pattern of ecotypic variation and should, therefore, be grouped together. But this, again, would not fit in with the logic of the Linnean hierarchy. The only way to get around the difficulty would be to break the taxa up into artificial assemblages.

Upon these considerations, it seems inescapable that some of the categories proposed by SCHILDER (1966) conflict with his avowed aim to "demonstrate his opinion about the phylogeny of the various taxa . . ." This is not to say that the groupings he suggests are unimportant for biology; they constitute a very useful part of systematic descriptions. However, certain types of variation, such as those seen in ecotypes and clines, are alien to the fundamental basis of classification. Nothing but chaos is gained by attempts to force such attributes upon the structure of Linnean hierarchies.

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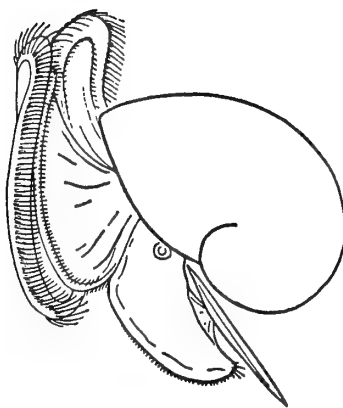
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## Observations on and Distribution of Some Western and Southwestern Mollusks

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DURING THE PAST TEN YEARS the senior author has accumulated considerable distributional data on several species of western mollusks, and those data are reported herein. The remaining observations were secured during August of 1959 in the mountain states of Arizona and New Mexico. Specimens collected in Sonora, Mexico have been discussed elsewhere (BRANSON, McCOY & SISK, 1964). With the exception of a few specimens deposited in the U. S. National Museum, all specimens were retained by the senior author. Dr. J. P. E. Morrison of the U. S. National Museum is thanked for verifying some of our identifications.

PILSBRY (1933) at Home Dale, Idaho, 62 miles to the north.

*Fluminicola columbiana* HEMPHILL, 1899

Dr. G. A. Moore, Oklahoma State University, kindly sent us 187 alcoholic specimens collected from the north fork of Clearwater River on 20 VIII 1958, three miles above Oksakka, Idaho. This species has been collected on several occasions near Weiser.

*Amnicola* (= *Paludestrina*) *longinqua* GOULD, 1855  
Eight dead shells were removed from the banks of Bear Lake, Idaho on 18 VIII 1961.

### Pulmonata

#### Prosobranchia

##### AMNICOLIDAE

*Amnicola idahoensis* PILSBRY, 1933

On 23 VIII 1955, 223 specimens of this pink-shelled species were collected from an irrigation ditch near U. S. Highway 30 in the Snake River Valley, Oregon, a locality immediately adjacent to Weiser, Idaho. The shells ranged from 4.3 mm to 7.8 mm in height, and 2.6 mm to 3.5 mm in greatest diameter. This collection apparently represents a new distribution record, the next nearest site is that of

##### HELICIDAE

*Monadenia fidelis* (GRAY, 1834)

Two living specimens were secured on 23 VIII 1962, Hoh River Rain Forest, Olympic National Park, two miles east of the Hoh River camp ground, Washington.

*Helix aspersa* MÜLLER, 1774

On 13 V 1959 two large specimens were taken from a truck farm in Los Angeles County, and ten from a similar situation in Fresno County, California. These are all the data supplied us by a student collector. From the literature at hand, the Fresno record seems to be a new one. However, these large European exotics are readily trans-

<sup>1</sup> Supported in part by National Science Foundation Grant G-4323

ported in vegetation, so the species is doubtless widespread in California. In some areas they pose an agricultural problem.

#### HELMINTHOGLYPTIDAE

##### *Helminthoglypta callistoderma* (PILSBRY & FERRISS, 1918)

On 4 VII 1959 Mr. Miles Eiseman collected a living animal near Hot Springs Ranger Station, near the 3000 foot elevation mark, Tulare County, California. Although the species is known from that county, this specimen is of some interest. Its mensurable characters are: diameter, 32.0 mm; height, 26.2 mm; there are exactly 6 whorls. The entire dorsum and sides of the soft anatomy are covered by black reticulations, the ground color being mollis-gray. PILSBRY's (1939) largest specimen measured 15.6 mm in height and 23.0 mm in diameter, possessing  $5\frac{1}{2}$  whorls. His color description, from a long-preserved specimen, indicated the body to be neutral gray and the reticulations to be restricted to the lung region.

##### *Sonorella granulatisima* PILSBRY, 1902

McCoy collected 22 specimens on 10 VIII 1958 from Ramsey Canyon, Huachuca Mountains, Cochise County, Arizona. These shells were taken from lichen-covered talus, at that time being very moist from recent rains. All specimens were more or less spirally striate on the last whorl. The mensurable details were: 8.5 to 17.6 mm in diameter; height, 5.2 to 9.6 mm; 3 to  $4\frac{1}{2}$  whorls. PILSBRY's (1905) descriptions taken from specimens secured in the same general locality are essentially identical to those observed by us. However, nine specimens collected on 22 VIII 1959 from nearby Carr Canyon did not demonstrate the variation in sculpture reported by PILSBRY in specimens taken from this canyon over 60 years ago. The shells are indistinguishable from those of Ramsey Canyon.

##### *Sonorella virilis* PILSBRY, 1905

A total of 43 beautiful specimens were secured from Cave Creek Canyon, Chiricahua Mountains, Arizona, on 12 VIII 1959. Twelve of these were found near 7000 feet M. S. L., and the others at approximately 6500 feet. They were all in the same sort of habitat described above for *Sonorella granulatisima*. At the time, a driving rain was falling, and snails were crawling everywhere, most of them in tandem, indicating that the breeding cycle is probably geared to the occurrence of rainfall rather than to a particular season of the year.

The striation on the last whorl varied from heavy to practically lacking. According to PILSBRY's (1905) description of the holotype, the back is "pebbly-granose," as it is in our specimens, and the color, including the eye stalks, was blackish-gray, the tail and sides being pale, dirty brownish-white. In the specimens examined by us, the tentacles, eyestalks and sides of the foot were brilliant orange in color, the back being more faintly

colored, slaty gray showing through. The probable reason for these differences is that the specimens observed by PILSBRY were collected during the dry season, and they were preserved in alcohol. The orange coloration is present during the mating season, and it very quickly fades in alcohol.

The shell varied from very dark to drab, faded. The penis, also bright orange, is of enormous length, being more than twice the length of the shell. The mensurable details of the shell follow.

Diameter	Height	Whorls
17.5 mm	10.0 mm	$4\frac{1}{4}$
20.5 mm	12.0 mm	$4\frac{3}{4}$
20.5 mm	11.5 mm	$4\frac{3}{4}$
7.0 mm	4.5 mm	$2\frac{3}{4}$

There is very broad overlap in the above measurements with those of *Sonorella virilis circumstriata* PILSBRY. Hence, the validity of that race is doubted.

##### *Oreohelix strigosa depressa* (COCKERELL, 1890)

During July of 1957, McCoy collected 121 typical specimens at Coulter Mesa, elevation 10000 feet mean sea level, 21 miles north of Rifle, Garfield County, Colorado, and 14 specimens from Freemont County. Both of the above localities are considerably farther south than the records listed by PILSBRY (1939). Four specimens were donated by Mr. Pat Miller, collected on 10 VI 1961 at the Dinosaur National Monument, Hardy's Hole, elevation 5700 feet, a sandy hillside above the Yampa River, in Colorado.

##### *Oreohelix subrudis* ("PFEIFFER," REEVE, 1854)

Nearly 400 living specimens were taken near Trappers Lake, Colorado in August 1954, at an altitude of approximately 12000 feet. As many as 50 specimens were removed from beneath a piece of debris measuring less than one square foot. This parallels a similar observation by HENDERSON (1936) in Yellowstone National Park. Another collection by McCoy netted over 200 specimens in Freemont County, Colorado on 18 VII 1957. Sixteen specimens were found on 20 II 1960, beneath *Cercocarpus* thickets and yucca,  $8\frac{1}{2}$  miles north of Boulder, Boulder County, Colorado, and one specimen was found beneath a stone on 11 IX 1960 in the Plateau Creek area, 5 miles east of the creek's mouth, Mesa County, Colorado. An older collection, 39 specimens associated with two living *Anguispira kochi occidentalis* on the littered forest floor at Pierce, Clearwater County, Idaho, is an additional locality for the species in that state.

##### *Oreohelix clappi* FERRISS, 1904

Eight pairs of *Oreohelix clappi* in copula were found at the Cave Creek station discussed under *Sonorella virilis*. The shell measurements for these specimens were: height,

8.0 to 9.2 mm; diameter, 14.2 to 16.0 mm; whorls,  $4\frac{2}{3}$  to 5. There is close agreement between our specimens and those of PILSBRY (1905), but in our opinion there is little reason to recognize the nominal subspecies *Oreohelix clappi emigrans* and *O. clappi cataracta* (PILSBRY & FERRISS, 1910).

#### AMMONITELLIDAE

##### *Polygyrella polygyrella* (BLAND & COOPER, 1861)

We follow WURTZ (1955) in separating the ammonitellids from the Camaenidae. Three living animals were collected from some moist pine duff in Clearwater County, Idaho, T39N, R5E, S23, on 4 VI 1956. This appears to be an additional locality for the species.

#### POLYGYRIDAE

##### *Triodopsis mullani olneyae* (PILSBRY, 1891)

Found with the *Polygyrella* were four living specimens of this large species, likewise a new distribution record.

##### *Allogona ptychophora lombardi* A. G. SMITH, 1943

The senior author secured one large specimen at the Clearwater County station in Idaho, and Mr. H. G. Stovall collected two in August of 1958, 15 miles north of Avery, Shoshone County, Idaho. All three specimens were living in moist forest litter. As both sites are new records, it would appear that this form is considerably more widely distributed than heretofore supposed. The shell characters agree closely with those given by SMITH (1943).

##### *Ashmunella rhyssa edentata* COCKERELL, 1900

Two dead shells and 12 living specimens were found at 8000 feet, one mile east of Cloudcroft, Sacramento Mountains, Otero County, New Mexico on 14 VIII 1958. These are virtual topotypes. After comparing these specimens with some of *Ashmunella rhyssa rhyssa* and *A. rhyssa miorhyssa*, it does not seem plausible to retain any of the subspecific epithets.

##### *Ashmunella townsendi* BARTSCH, 1904

Thirty-seven large specimens were collected during a rain storm near the entrance into the Mescalero Apache Reservation, near Ruidoso, White Mountains, at approximately 7000 feet elevation, on 10 VIII 1959. They were very abundant beneath decaying logs, some pairs in copula. Virtual topotypes.

##### *Ashmunella mogollonensis* (PILSBRY, 1905)

Six specimens were found associated with the *Sonorella virilis* discussed above. The following mensurable characters were secured from them: height, 9.3 to 10.5 mm; diameter, 19.5 to 21.5 mm; whorls,  $5\frac{1}{4}$  to  $5\frac{3}{4}$ .

##### *Ashmunella ferrisi* PILSBRY, 1905

Also associated with the *Sonorella virilis* were 49 living specimens of this peculiar species, many of which were in mutual tandem. Mensurable details follow.

Diameter	Height	Whorls
4.4 mm	2.0 mm	3
11.5 mm	5.0 mm	$6\frac{1}{2}$
12.0 mm	5.5 mm	$6\frac{1}{2}$

Although PILSBRY (1905, 1940) and PILSBRY & FERRISS (1910) reported this species as occurring only at the foot of Reeds Mountain in the Cave Creek Valley, our collecting site was some five to six miles up the valley. This form is doubtless more widely distributed in the inter-connected valley systems of this region.

##### *Ashmunella levetti* (BLAND, 1882)

On 10 August, 1958, McCoy found only six specimens near the type locality, Ramsey Canyon, 7000 feet, in the Huachuca Mountains, Cochise County, Arizona. At that time the rocks were dry and the temperature  $96^{\circ}$  F. On 22 August, 1959, the temperature was only slightly in excess of  $70^{\circ}$  and rains were occurring regularly. The species was abundant on talus slides, and the authors secured 65 specimens in a few minutes, near Carr Canyon at approximately 8000 feet altitude, M. S. L. Measurements ranged from 6.0 mm in diameter, 3.0 mm in height and slightly more than 3 whorls, to 13.0 mm in diameter, 5.8 mm in height,  $6\frac{3}{4}$  whorls.

According to distribution our specimens should be *Ashmunella levetti angigyra* PILSBRY. However, there seems to be little reason to recognize these so-called races. In this area, such "subspecies" are imaginary.

There is practically nothing known concerning the breeding habits, life history and cytology of the mountain gastropods of western North America. Moreover, there is a great deal of information yet to be gleaned concerning ecological affinities, basic morphology and taxonomy of the species occupying the lesser mountain ranges in Arizona and New Mexico.

#### SAGDIDAE

##### *Thysanophora horni* (GABB, 1866)

Eleven dead shells were separated from drift material deposited by the San Pedro River near Hereford, Cochise County, Arizona, 22 VIII 1959. All were rather typical of that species.

#### HAPLOTREMATIDAE

##### *Haplotrema vancouverense* (LEA, 1839)

One specimen, 26.0 mm in greatest diameter, was donated by Dr. B. P. Glass, Oklahoma State University, collected on 20 VI 1960 in the Olympic National Park, Surprise Valley, Jefferson County, Washington. Neither HENDERSON (1929) nor BAKER (1930) reported the species from this locality.

## ZONITIDAE

*Euconulus fulvus alaskensis* (PILSBRY, 1899)

A single specimen was collected from deep leaf mold at the White Mountains site. In addition, McCoy took six living specimens at a locality one mile north of the Y.M. C. A. camp, near Glacier Creek, Estus Park, Larime County, Colorado. This species' range is known to extend southward to at least the Mexican border at high altitudes in the Chiricahua and Huachuca mountains (PILSBRY & FERRIS, 1910, 1915). Although *Euconulus fulvus* has been found in the Whites (PILSBRY & FERRIS, 1918), the so-called race *alaskana* has not. It is doubtful whether this form merits recognition.

*Retinella indentata* (SAY, 1823)

Four living specimens were found with the *Sonorella virilis*, and one dead shell was removed from the San Pedro River drift. This species was reported from the Cave Creek Canyon by PILSBRY & FERRIS (1906).

*Retinella electrina* (GOULD, 1841)

Three specimens from the Estus Park station.

*Hawaiiia minuscula* (BINNEY, 1840)

Over 100 shells were taken from some drift material on the banks of the Pecos River at the point where the stream crosses U. S. Highway 66, near Santa Rosa, New Mexico, and nearly 1000 from a similar situation at the San Pedro in Arizona. This species is quite generally distributed throughout the flatlands.

*Zonitoides arboreus* (SAY, 1816)

One specimen removed from drift on the banks of the Zuni River, near St. Johns, Apache County, Arizona, 25 VIII 1959; two living specimens at the Mescalero Apache Reservation; 84 shells at a locality eight miles west of Boulder, Colorado; and 73 at the Estus Park station.

*Vitrina alaskana* DALL, 1905

Two living specimens collected from beneath box elder duff at approximately 6000 feet, four miles west of Angus, Philadelphia Canyon, Lincoln County, New Mexico, 11 VIII 1959. The shells were very membranous, scarcely impregnated with calcium. An additional 22 shells were located at the Estus Park site.

## LIMACIDAE

*Deroceras laeve* (MÜLLER, 1774)

Associated with the *Vitrina alaskana* was a single specimen of this small, nearly black and nearly ubiquitously distributed slug. McCoy collected 12 specimens at the Estus Park site, and one from a flower garden in Boulder, Colorado, 2 IX 1960.

*Limax flavus* LINNAEUS, 1758

Seven large specimens removed from some water meters in Fresno, Fresno County, California, 13 V 1959.

The records for the last two species are apparently new.

*Limax valentianus* FÉRUSAG, 1823

Three of these small, longitudinally banded, tan slugs were taken with the *Limax flavus*. A new record for this European exotic.

## ENDODONTIDAE

*Anguispira kochi occidentalis* (VON MARTENS, 1882)

One living specimen was found with the *Oreohelix subrudis* at Pierce, Idaho, and one dead shell with the *Allogona* in Shoshone County, Idaho.

*Discus shimeki* (PILSBRY, 1890)

Twenty-seven living specimens were collected on 16 VIII 1960 from beneath some boulders at 10000 feet, near Eldora, Boulder County, Colorado, and 13 at Estus Park.

*Discus cronkhitei* (NEWCOMB, 1865)

McCoy secured 14 specimens at the Estus locale, this representing a new record.

*Helicodiscus eigenmani arizonensis*

PILSBRY & FERRIS, 1906

One specimen from the banks of the Salt River, U. S. Highway 60, Gila County, Arizona on 24 VIII 1959, and six from the banks of the Pecos River, Santa Rosa, New Mexico. Both are new records for this form. As pointed out elsewhere, there are reasons for doubting the validity of *Helicodiscus eigenmani*, primarily because the form tends to grade to *H. parallelus* in the east. Specimens from western Oklahoma, especially in Cimarron and Texas counties, and from western Kansas are equally as large and as well-marked as specimens from the Rockies and their outliers. Statistical evaluation of a large series would probably demonstrate an east-west cline as regards size and shell sculpturing.

*Helicodiscus singleyanus* (PILSBRY, 1890)

Six dead shells removed on 23 VIII 1959 from the banks of the Gila River, one mile north of Florence, Pinal County, Arizona. A new distribution record in Arizona.

## ARIONIDAE

*Prophysaon humile* COCKERELL, 1890

One small specimen of this peculiar slug was collected with the *Polygyrella* in Idaho. From the genitalia, it would appear that some taxonomic reconsiderations are in order. They are suspiciously like those in the Polygyridae.

*Ariolimax columbianus* (GOULD, 1851)

Three specimens, 32.0, 90.5 and 92.0 mm in total length (alcoholic), were secured by Dr. B. P. Glass at his Washington collecting station. HENDERSON (1929) did not mention this locality. Two typical specimens were collected by the senior author from beneath a fallen western red cedar on 23 VIII 1962, two miles east of the Hoh River camp grounds, Olympic National Forest, Washington.

## SUCCINEIDAE

*Catinella vermata* (SAY, 1829)

One dead shell from the Zuni River drift and another one at the San Pedro station. McCoy secured three living specimens on the banks of Warm Springs Creek, near its confluence with the Yampa River, Moffat County, 10 VI 1961, one from a dry irrigation ditch at Canyon City, Fremont County, 2 IX 1960, and two at the Estus Park site, all in Colorado.

## PUPILLIDAE

*Gastrocopta proarmifera* LEONARD, 1946

A single specimen, doubtless washed downstream from some outcropping, of this Pleistocene fossil was found on the banks of the Green River, U. S. Highway 50, on 28 VI 1963, Utah. It measures 4.2 mm in height, 2.3 mm in diameter and has 6 whorls. The spur is well developed on the parietal tooth.

*Gastrocopta armifera* (SAY, 1821)

Seven shells, corresponding to Sterki's nominal subspecies *Gastrocopta armifera abbreviata* were found at the Santa Rosa station in New Mexico.

*Gastrocopta tappaniana* (C. B. ADAMS, 1842)

A single shell was taken at the San Pedro station.

*Gastrocopta quadridens* PILSBRY, 1916

Two specimens of this distinct species were collected from the Salt River locality, a considerable distance from the nearest northern record (Chiricahua Mountains).

*Gastrocopta perversa* (STERKI, 1898)

One specimen each from the Gila and Salt River sites. The latter is a new distributional record. All previous records are from southeastern Arizona.

*Gastrocopta ashmuni* (STERKI, 1898)

Three specimens from the drift at the Salt River station.

*Gastrocopta cochisensis* (PILSBRY & FERRISS, 1910)

A single shell of this relatively uncommon snail from the San Pedro drift represents a new distribution record for the species.

*Gastrocopta oligobasodon* (PILSBRY & FERRIS, 1910)

Two shells from the San Pedro drift. This species doubtless is more widely distributed than the paucity of records indicates. However, the species may be only a variant of *Gastrocopta cochisensis*.

*Gastrocopta dalliana* (STERKI, 1898)

Fifteen shells were found in river drift, seven at the Salt, four at the Pecos, and four at the San Pedro. The Gila County record is an additional site in Arizona, and the one at Santa Rosa is an addition to the known fauna of New Mexico. Intensive collecting in Arizona and New Mexico will probably disclose several species heretofore regarded as rare or narrowly restricted in range. Valley systems allow migratory pathways around the bases of otherwise dry mountain areas.

*Gastrocopta bilamellata* (STERKI & CLAPP, 1909)

A single shell from the Gila River station represents a new site for the species, indicating this species' range to be farther east and north than supposed by PILSBRY (1948).

*Gastrocopta procera* (GOULD, 1840)

The following are localities from which specimens were secured, the number collected from each locality is in parentheses before the station: (1) Salt River; (23) Pecos River; (58) San Pedro River.

Nine of the Pecos specimens, 20 of the San Pedro, and the single specimen from the Salt River station were of the *Gastrocopta procera mclungi* (HANNA & JOHNSTON) type, or approximately one-half of the composite lot. Furthermore, there is considerable variation in the other specimens. The authors agree with FRANZEN & LEONARD (1947) that this name should be suppressed as a synonym.

*Gastrocopta cristata* (PILSBRY & VANATTA, 1900)

The records for this species are: (1) Gila River; (8) Zuni River; (1) Salt River; (20) Pecos River; and (123) San Pedro River.

*Gastrocopta pellucida* (PILSBRY, 1890)

As in *Gastrocopta procera*, two shell-morphs were observed in this species; *G. pellucida hordeacella* (PILSBRY), one specimen from the Gila and nine from the Pecos River station; and *G. p. parvidens* (STERKI), seven from the Salt and three from the Pecos River station. Although these are new distribution records, the more important point to be made here is that both "races" were collected in the same localities, relatively widely separated from one another. From this observation, and from considerable other evidence, it seems apparent that these names should be suppressed.

*Chaenaxis tuba* (PILSBRY & FERRISS, 1906)

Four specimens of this curious species were secured at the Gila River station, representing a new distribution record.

*Pupoides albilabris* (C. B. ADAMS, 1841)

Four specimens from the Gila River station, two at the Pecos, and 36 from the San Pedro. The first two are additional distribution records.

*Pupoides hordaceus* (GABB, 1866)

Ten shells at the Zuni station; one at the Pecos. Both are new distribution records.

*Pupilla sonorana* (STERKI, 1899)

Eight living specimens at the Philadelphia Canyon locality in New Mexico, a new locality for the species.

*Pupilla blandi* MORSE, 1865

Four dead shells were removed from the Pecos River drift material. These may or may not be Pleistocene fossils, since the periostracum is still intact.

*Pupilla syngenes* (PILSBRY, 1890)

One specimen found at the Salt River locality, an additional site for the species in Arizona.



*Vertigo milium* (GOULD, 1840)

One specimen found in the Zuni River drift.

*Vertigo ovata* SAY, 1822

Six typical specimens found at the San Pedro station.

*Vertigo binneyana* STERKI, 1890

Three specimens were secured from the drift of the San Pedro River. A new addition to the known fauna of Arizona, and the farthest west it has been found to date.

## VALLONIIDAE

*Vallonia gracilicosta* REINHARDT, 1883

Four specimens from the Pecos locality represent an additional site in New Mexico.

*Vallonia perspectiva* STERKI, 1892

Four shells were found at the Salt River station, another site for the species in Arizona.

*Vallonia cyclophorella* STERKI, 1892

Four living specimens were removed from box elder duff in Philadelphia Canyon, and McCoy collected six shells at the Estus Park station.

## CIONELLIDAE

*Cionella lubrica* (MÜLLER, 1774)

One specimen each at the Salt River and Philadelphia Canyon stations are both new localities and the most eastern records in the respective states.

## LYMNAEIDAE

*Lymnaea bulimoides* LEA, 1841

Three specimens collected at the San Pedro station.

*Lymnaea humilis* SAY, 1822

One specimen taken at the San Pedro station, and two living specimens from a prairie marsh one mile south of Boulder, Colorado (22 XI 1960). PILSBRY & FERRISS (1915) recorded this species under the epithet *Lymnaea parva*, which is considered as a synonym (HUBENDICK, 1951).

*Lymnaea palustris* (MÜLLER, 1774)

One specimen collected from the prairie marsh south of Boulder, Colorado.

*Lymnaea utahensis* (CALL, 1884)

Six specimens were collected on 18 VIII 1961 at Bear Lake, Idaho. The authors agree with HUBENDICK (1951) that this form looks suspiciously like a variant of *Lymnaea bulimoides*.

## PHYSIDAE

*Physa virgata* GOULD, 1855

Approximately 50 living specimens were collected from the moderately flooded waters of the Rio Hondo at Sunset, Lincoln County, New Mexico (10 VIII 1959), one at Bear Lake, Idaho, and one immature shell at the San Pedro River. PILSBRY & FERRISS (1915) found the species at the last-named locality. This is a widespread

form in the mountains, its range extending all the way to the Gulf of California in Mexico.

*Physa anatina* LEA, 1864

McCoy collected 11 living specimens from the prairie marsh south of Boulder which seem to be this species, a widespread form in the Great Plains.

## PLANORBIDAE

*Gyraulus parvus* (SAY, 1817)*Gyraulus carus* PILSBRY & FERRISS, 1906*Taphius decipiens* (C. B. ADAMS, 1849)

The above species, seven of the first, five of the second and seven of the third, were collected at the San Pedro station. *Taphius decipiens* is a beautiful, but poorly understood species, the synonymy of which has recently been discussed by BRANSON, MCCOY & SISK (1964). The center of abundance seems to be in Mexico, especially in the Rio Sonora and associated drainages.

*Gyraulus circumstriatus* (TRYON, 1866)

One specimen from the Zuni River represents a new distribution record in Arizona.

*Gyraulus similis* (F. C. BAKER, 1917)

Five dead shells were secured from the Salt River station in Arizona.

*Gyraulus vermicularis* (GOULD, 1847)

One living specimen was removed from the underside of a floating piece of bark at the Green River site. It measured 3.3 mm in diameter, 1.0 mm in height, and possessed slightly more than 3½ whorls. CHAMBERLIN & JONES (1929) listed several Utah localities, but none so far east. The type locality is in Oregon.

*Gyraulus umbilicatellus* (COCKERELL, 1885)

McCoy collected a single dead shell from a pool approximately eight miles west of Boulder, Colorado. It may have been washed from higher elevations.

*Helisoma trivolvis* SAY, 1817

Five specimens collected on 3 IV 1963 at 6000 feet elevation, near Canyon City, Colorado are impossible to distinguish from this species. Some representative measurements are:

Diameter	Height	Whorls
11.0 mm	7.5 mm	3½
12.5 mm	6.6 mm	4+
16.6 mm	8.3 mm	4¾

*Helisoma tenue sinuosum* (BONNET, 1864)

Hundreds of individuals were observed in the spring-fed pools of the old "Texas-John" Slaughter Ranch, now called the "Williams" Ranch, south of Douglas, Arizona on 27 I 1962. Nine specimens were collected for the record.



*Carinifex newberryi* (LEA, 1858)

One hundred and thirty-six dead shells were scooped up with one motion of a quart jar at the Bear Lake station. Thousands of shells lay on the beaches.

## PELECYPODA

*Pisidium casertanum* (POLI, 1791)

McCoy collected 50 living specimens of this small sphaeriid from the prairie marsh south of Boulder.

*Sphaerium striatinum* LAMARCK, 1818

Ten dead shells were collected with the *Carinifex* listed above. They are all of the *pilsbryanum* STERKI type (HERRINGTON, 1962).

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# A Remarkable Snail Fauna from Coahuila, México

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(Plates 8 to 19; 25 Text figures)

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(1) Nowhere else in North America are there 5 genera restricted to such a small area. In the Western Hemisphere the only parallel is Lake Titicaca, Bolivia-Perú, to which several genera of snails are peculiar.

(2) Nowhere else in the Western Hemisphere has the evolution of species from a common ancestor taken place in such a local area. The closest parallel among snails is found in some of the land snails of some mountains in the southwestern U.S.A., or of islands in the Pacific Ocean or West Indies, where each separate valley or limestone hill seems to have a slightly different assemblage with unique forms. Among freshwater snails such a close grouping of related species is unknown elsewhere.

(3) Most of the species are strikingly distinct in their shape or coloration. They are more like marine snails in this than like the ones to which their anatomy shows relationships.

(4) Although a number of species are restricted to a single spring, others found with them are widespread in the basin. Such an association provides a remarkable opportunity to study speciation in a natural laboratory.

(5) Spectacular though the first discoveries are, only one habitat has been reasonably well sampled – the large warm springs. Other situations, for example the subterranean rivers, have never been examined; hence still other significant findings are possible.

The traveler who visits México may well echo the popular statement "¡Como el México no hay dos!" (there are no two places like Mexico). A scientist can be more specific: ¡Como el valle de Cuatro Ciénegas no hay dos!

## INTRODUCTION

THE TOWN OF Cuatro Ciénegas de Carranza lies in a valley about 40x30 km, enclosed by ranges of the Sierra Madre Oriental in central Coahuila, México. The snails of this valley are unique in North America, perhaps in the world:

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## DESCRIPTION OF AREA

The valley including Cuatro Ciénegas de Carranza (Text figures 1, 2) is roughly in the shape of a horseshoe open to the south, 40 km east-west, and 30 km north-south. The horseshoe is divided by the NNW-trending spur called Sierra de San Marcos. Cuatro Ciénegas de Carranza (population 3931) is the capital of the Municipal Cuatro Ciénegas, a subdivision of the state of Coahuila. In vegetation the area is part of the Chihuahuan Desert.

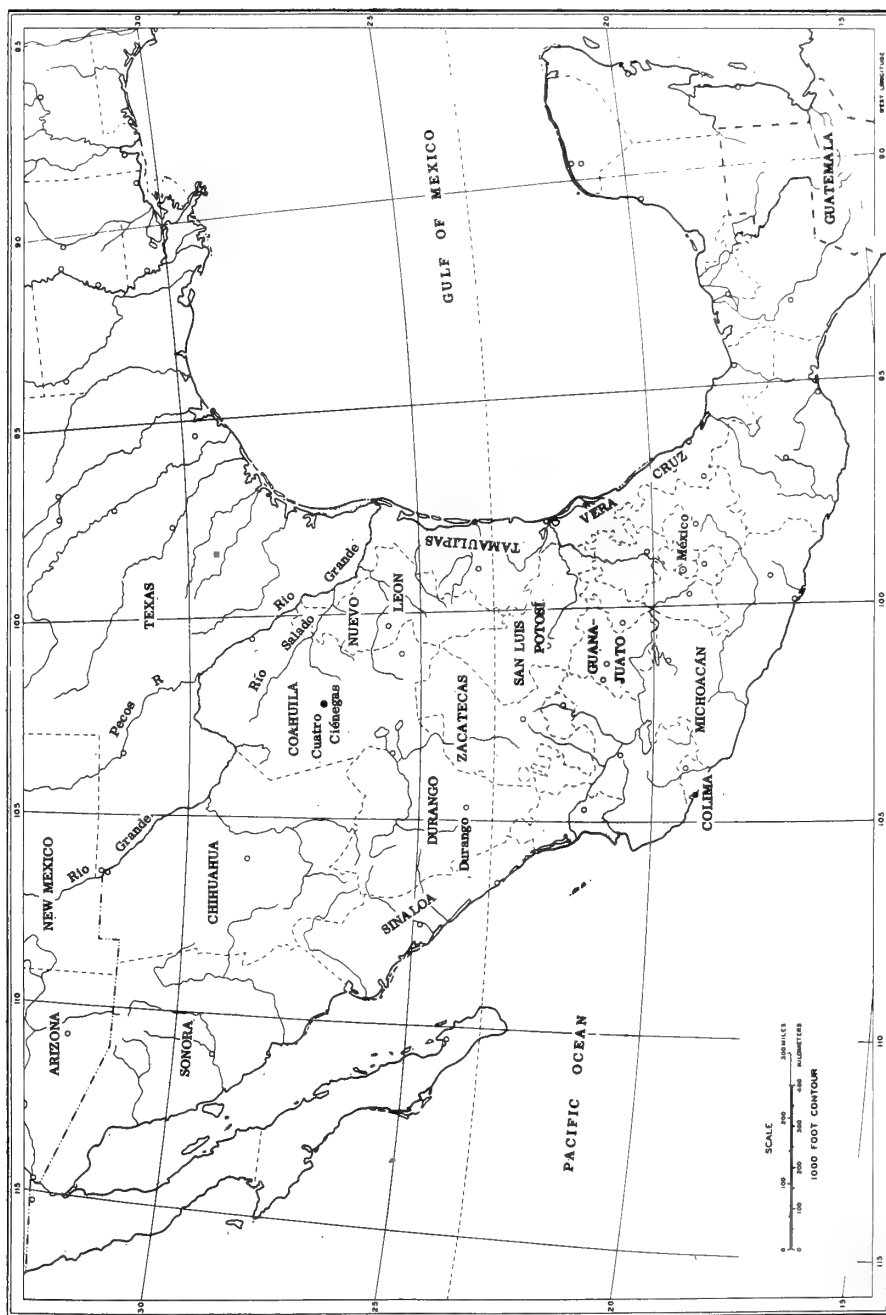


Figure 1

Index map of México, showing location of Cuatro Ciénegas and states mentioned in the text.

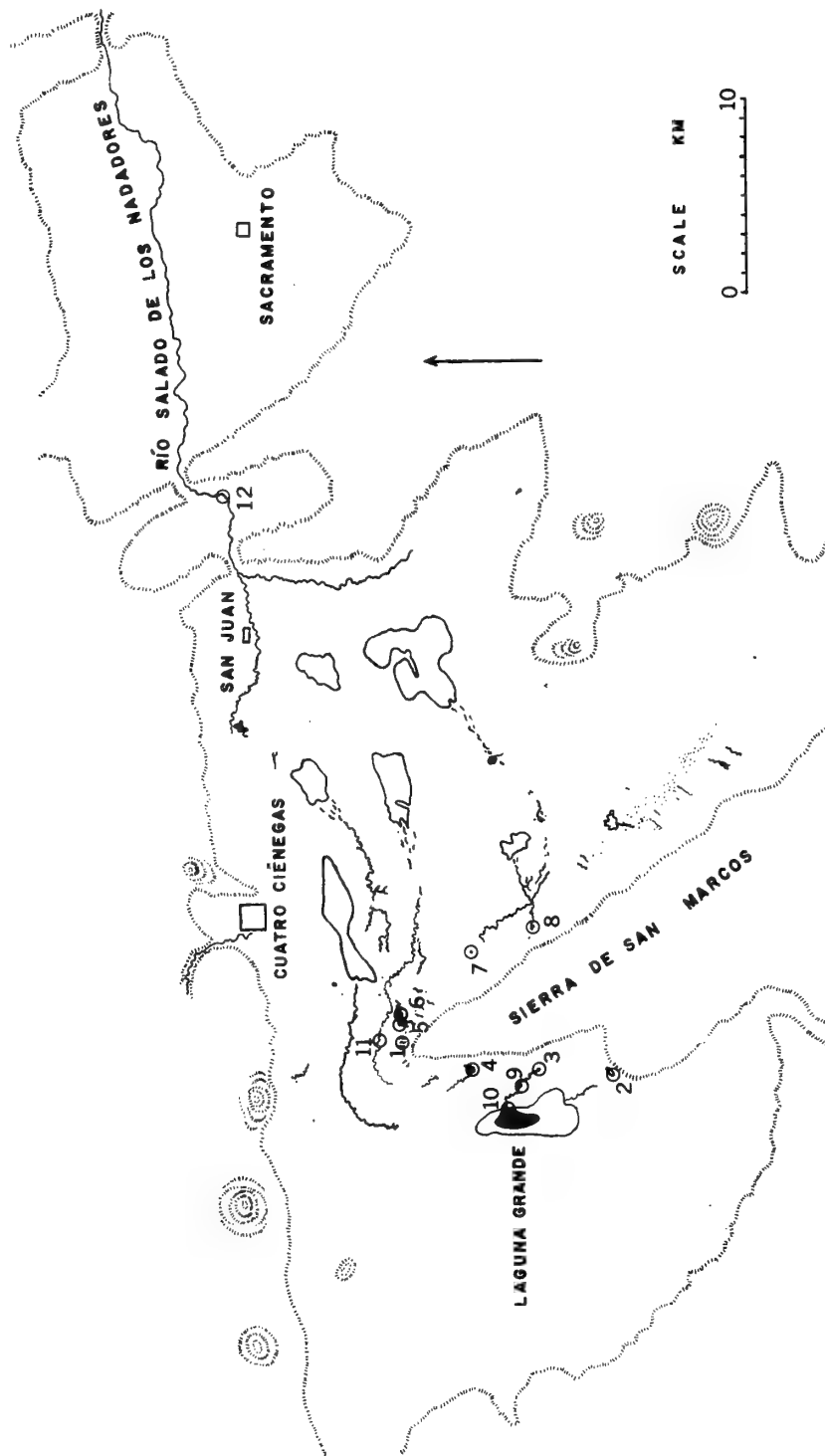


Figure 2

Index map of the valley of Cuatro Ciénegas. Mollusk localities are circled; the numbers correspond to those in the locality descriptions.  
 Base prepared by W. L. Minckley, from field reconnaissance and unpublished sources.

The mountains are steep, bare limestone, all Cretaceous according to the "Carta geológica de la República Mexicana, escala 1:2 000 000, 1960." The valley lies within the Mesa del Norte (Altiplanicie Septentrional) geomorphic region of West (1964), whose paper includes an aerial photograph (fig. 9) of the basin that lacks detail useful for discussion of specific localities. Elevation of the area is a little over 700 m above sea level; the railroad station of Cuatro Ciénegas is 742 m above sea level.

The drainage of the area is both greater in volume and more complex than one expects in a desert region. Surely both of these unusual features are linked with the remarkable fauna. There are at least 5 main separate surface drainages in this small area. One includes the southern end of the western arm of the horseshoe: water flows into a saline lake, Laguna Grande (Text figure 2, locality 10), principally from the spring Churince (Text figure 2, locality 3) through the Río Churince. Waters from Pozos de la Becerra (Text figure 2, locality 4) might once have flowed into Laguna Grande, but have now been canalized northward. The second drainage is the Río Mesquites system, including localities 5-8 and 11 on Text figure 2. This was originally internal drainage but now flows through canals into the Río Grande. The third drainage is that of Río Garabatal, the farthest northwest of the tip of Sierra de San Marcos. Its originally internal basin received waters from the northern bordering mountains before canalization. The fourth drainage is that naturally tributary to the Río Grande by way of the Río Salado de los Nadadores in the northwestern corner of the Cuatro Ciénegas basin. The last drainage is the isolated lagunas of the area north and west of Rancho Santa Tecla. Isolated waters also are known besides those included in the preceding.

The previously available published maps are inadequate to show local details of the snail distribution. All mollusk localities within the valley of Cuatro Ciénegas are shown on sheet 13R-VI (Jimenez) of the Carta Geográfica de la República Mexicana (1958) 1:500 000; and on sheet NG 13 (Culiacan) of the Map of Hispanic America (American Geographical Society, 1935, scale 1:1 000 000). The locality known as El Cariño that is just outside the east edge of the valley of Cuatro Ciénegas, mollusks from which are reported herein, is included within the 14R-V (Nuevo Laredo) sheet of the Carta Geográfica de la República Mexicana.

Aside from the town of Cuatro Ciénegas de Carranza, hereafter referred to as simply Cuatro Ciénegas, few of the local place names appear on the maps mentioned, and these are mislocated. Laguna Grande is unnamed, but correctly located, on the Jimenez sheet 17 km southwest of Cuatro Ciénegas. Pozo de la Becerra is shown wrongly on that map as south of the Laguna, rather than north. El Mojarral is the local name for an area of

marshes, springs (pozos), and large spring pools (lagunas) east of the northern end of Sierra de San Marcos. On the Jimenez sheet it appears wrongly as a settlement to the west of that mountain. El Bañito of the Jimenez sheet, 12 km south of Cuatro Ciénegas, is probably the laguna known locally as Escobeda. There is no longer a settlement there. Distances and directions given herein are from a base map prepared by W. L. Minckley (Text figure 2).

Despite the negligible amount of municipal pollution, a few populations and species have already been extinguished and others are threatened. Artificial lowering of water levels by digging irrigation canals has locally destroyed some habitats and will affect others. Another, slower effect of the canal system will be the mixing of streams and populations that were naturally separate. This change has begun to affect the fishes, but in the present state of scanty knowledge of the mollusks one cannot find evidence for it, nor rule it out completely.

## HISTORY OF RESEARCH

The first biologist to visit the Cuatro Ciénegas area was E. G. Marsh, Jr. who obtained a variety of vertebrates there and elsewhere in the Río Salado drainage during 1939. To him belongs the credit for discovery of the remarkable endemic fauna of fishes and reptiles. W. L. Minckley began a series of trips in 1958, resulting in visits by various herpetologists and ichthyologists, including C. L. Hubbs and R. R. Miller. HUBBS & MILLER (1965) have summarized the history of vertebrate study, and the literature to date.

The earliest collection of mollusks was made by C. L. Hubbs in 1961, and subsequently sent to me for study. From the shells it was evident that a novel fauna had been found, but no serious study could be undertaken without a chance to visit the area and collect fresh material. Continued studies by W. L. Minckley meanwhile revealed that the cichlid fish genus *Cichlasoma* included cryptic species, one of which was adapted to feed entirely on snails. Early in 1965 he brought samples of *Mexipygus*, *Mexithauma*, and *Nymphophilus* in alcohol that I identified as remarkable Hydrobiidae, and he offered an instantly accepted opportunity to visit Cuatro Ciénegas.

Thanks to the support of the University of Michigan, provided by Dr. Henry van der Schalie, I was able to join Minckley in El Paso, Texas, on April 9, 1965, for 3 days of collecting in western Texas and 4 in Coahuila.<sup>2</sup> The localities visited in the Cuatro Ciénegas area are

<sup>2</sup> Travel expenses of W. L. Minckley and students were supported by a grant for study of the genus *Cyprinodon* from the National Science Foundation, GB-2461, that thus had the unforeseen but happy result of also supporting this research on mollusks.

those considered most productive among many previously visited by Minckley. No thorough survey of the region could be made in this first visit. The notes and collections made during this trip, supplemented by the specimens collected previously by C. L. Hubbs and W. L. Minckley, were studied at the Museum of Zoology, University of Michigan. No field study of living snails with a microscope was practicable. Investigation of the anatomy of some forms, and further study of the relations between Hydrobiidae and Bithyniidae, was possible through facilities of the Hydrobiological Research Station of the University of Kyoto on Lake Biwa, Japan.<sup>3</sup>

As usual in freshwater mollusks, the investigation of the species and an attempt to put them into a framework of available knowledge revealed many uncertainties in morphology, biology and geographic distribution. Some of the snails from the valley of Cuatro Ciénegas evidently are closely related to others found outside, and I have reviewed such groups cursorily. A well-founded interpretation of the markedly distinctive genera will not be possible until the molluscan fauna of much of northern México is better known.

As study progressed, it quickly became evident that no thorough study of the fauna was possible with the material available. Two genera (*Coahuilix* and *Paludiscala*) were recognized only after return to the laboratory, and the living specimens of other genera brought back survived only a short time. Hence this paper barely puts the mollusks from the region of Cuatro Ciénegas into the available context of knowledge, diagnoses the new groups, and outlines problems for further study. The data published herein include only a part of the morphological information at hand, but are adequate to show that the new genera and subfamilies have been established as part of a search for relationships and not merely differences.

## COMPOSITION OF FAUNA

As classified herein the following freshwater mollusks are known from the valley of Cuatro Ciénegas:

### GASTROPODA

#### Prosobranchia

#### MESOGASTROPODA

##### RISSOACEA

##### HYDROBIDAE

##### Hydrobiinae?

#### Hydrobiidae, incertae sedis.

##### Cochliopinae

R<sup>4</sup> *Cochliopina milleri* TAYLOR, spec. nov.

RR\* *Coahuilix hubbsi* TAYLOR, gen. et spec. nov.

##### Littoridininae

R *Durangonella coahuilae* TAYLOR, spec. nov.

\* *Durangonella*, another species?

RR *Mexipyrgeus carranzae* TAYLOR, gen. et spec. nov.

RR *M. churinceanus* TAYLOR, spec. nov.

RR *M. escobedae* TAYLOR, spec. nov.

RR *M. lugoi* TAYLOR, spec. nov.

RR *M. mojarralis* TAYLOR, spec. nov.

RR *M. multilineatus* TAYLOR, spec. nov.

\* Littoridininae, incertae sedis

##### Nymphophilinae

RRR *Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

#### HYDROBIDAE?

##### Mexithaumatinae

RRR *Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

##### Paludiscalinae

RRR\* *Paludiscala caramba* TAYLOR, gen. et spec. nov.

#### ASSIMINEIDAE

\* *Assimineia* sp.

### Euthyneura

### BASOMMATOPHORA

#### ANCYLACEA

##### PLANORBIDAE

\* *Drepanotrema?* sp.

#### PHYSACEA

##### PHYSIDAE

*Physa virgata* GOULD

The high percentage of new genera and species is evident; this aspect of the fauna is discussed under "Biogeography" below. Another striking aspect of the fauna is the dominance of Rissoacea: all but 2 of about 18 species. In part this is due to the fact that the collections are all from a limestone terrain, and mostly from springs. (Even in the mixed sedimentary-volcanic region of southwestern United States I have found that source areas of springs are usually inhabited mainly by Hydrobiidae among the snails). Yet some localities looked suitable for other mollusks; especially the clam *Pisidium* (Sphaeriidae), and snails of the genera *Bakerilymnaea*, *Fossaria* (Lymnaeidae), *Planorbella*, and *Biomphalaria* (Planorbidae) might

<sup>4</sup> RRR Subfamily known only from the valley of Cuatro Ciénegas

RR Genus known only from the valley of Cuatro Ciénegas

R Species known only from the valley of Cuatro Ciénegas

\* Species known only from empty shells

<sup>3</sup> Research supported (in part) by National Science Foundation grant GB-3006.

be expected. Perhaps the composition of the water is partly responsible, as well as lack of intensive search.

## BIOGEOGRAPHY

There are two general ways of studying the geographic (rather than ecologic) distribution of living organisms. One is to classify regions on the basis of the geographic range of a taxonomic group, or several groups, of animals or plants. The other is the comparative analysis of distribution, using such features as areas of greatest diversity, centers of endemism, and degrees of relationship to judge the evolution of patterns of distribution. One is descriptive, the other analytical.

Both of these methods have advantages. When dealing with a single group such as birds or reptiles, faunal provinces are useful concepts to show what large areas have generally similar faunas. Yet their boundaries are arbitrary and hence at a large scale they lose usefulness. Different organisms can evolve at different rates too, so that even combining land snails and aquatic snails to classify a region leads to difficulties. A zoogeographical scheme including both mammals and fishes could scarcely be useful on account of the different ecologic limits, modes of life, and rates of differentiation of the animals concerned, and similarly "faunal provinces" based on vertebrates are not useful for even describing, let alone understanding the distribution of mollusks. Yet since so little is known about the aquatic mollusks of northern Mexico, and tropical America in general, a regional classification into roughly defined faunal areas is useful for organizing that present knowledge.

An analysis of patterns of distribution, and the comparison of centers of endemism (TAYLOR 1966a), require more detailed knowledge than simply classifying a region, but they also yield more detailed knowledge. I have summarized the geographic distribution of the Littoridininae, the one group of snails with a fossil record pertinent to the Cuatro Ciénegas area, in order to show the value of this kind of study even when the available data are scanty.

### "Faunal regions" of freshwater mollusks in northern México

Scientific knowledge of the freshwater mollusks of México and Central America up to about 1900 has been summarized in the great works by FISCHER & CROSSE (1870-1902) and MARTENS (1890-1901). Subsequent information is included in scattered papers and has never been summarized, but even today most of northern México and the adjacent U.S.A. are scarcely known. Most of the literature since 1900 is listed in Table 1. The follow-

Table 1

Literature on the freshwater mollusks of regions around the state of Coahuila. Those cited in the summaries by FISCHER & CROSSE (1870 to 1902) and MARTENS (1890 to 1901) have not been included consistently.

#### Drainage of Rio Grande (Río Bravo del Norte)

- a) in New Mexico, U.S.A.: F.C. BAKER (1911, 1945), BRUES (1928), COCKERELL (1896, 1902a), CRANDALL (1901:44), DALL (1896), DRAKE (1947), HENDERSON (1917, 1933), MEARNES (1907: 77), PILSBRY (1899a, 1900a, 1900b, 1906, 1916-1917), PILSBRY & COCKERELL (1900), PILSBRY & FERRISS (1906, 1909, 1917), SPRINGER (1902), WALKER (1915).
- b) in Texas and adjacent México: ALBRITTON & BRYAN (1939), F. C. BAKER (1911, 1945), CHEATUM (1935), CLENCH (1924), DALL (1896), DRAKE (1947), FERRISS (1924), HEARD (1963), LEA (1857, 1860c), LEONARD & FRYE (1962), LEONARD & HO (1960a, b), PILSBRY (1935b), PILSBRY & FERRISS (1906), SINGLEY (1893), STEARNS (1891), STRECKER (1931, 1935).

#### Balcones Escarpment, south-central Texas, U. S. A.

F. C. BAKER (1911, 1945), CALL & PILSBRY (1886), CHEATUM & MOUZON (1934), DRAKE (1947), GOODRICH (1942), HUBRICHT (1940), PILSBRY (1887, 1916), PILSBRY & FERRISS (1906), SINGLEY (1893), STERKI (1898), STRECKER (1935), WALKER (1909).

#### Chihuahua

DALL (1896), DRAKE (1953, 1956), PILSBRY (1895, 1928).

#### Nuevo Leon

DALL (1895: 6, 1896: 371), LEA (1860a, b, c), PILSBRY (1904), STEARNS (1891).

#### Tamaulipas

LEA (1857, 1860c), PILSBRY (1928), STEARNS (1893), THOMPSON (1959).

#### San Luis Potosí

BRANSON & MCCOY (1963), CHEATUM (1939), DALL (1905, 1908), FRIERSON (1907), HINKLEY (1907a, b), ORTMANN (1912: 271, 319, 332), PILSBRY (1909, 1910a, b, c, 1919, 1956), PILSBRY & FRIERSON (1907 - 1908), PILSBRY & HINKLEY (1907, 1910).

ing paragraphs outline the 5 geographic areas into which México could be divided according to distribution of freshwater mollusks. The endemic genera have been mentioned for each area, but no endemic species, nor all range limits of widespread genera. For comparison of the distribution of freshwater fishes, see MEEK (1904).

I. Central Plateau and Northwestern México. The only group restricted to this large area is the mussel *Arnoldina*, described from the headwaters of Río Yaqui, on the boundary between Sonora, México, and Arizona, U.S.A. The hydrobiid snail *Durangonella* is known both from this region and western México and so might be considered a second restricted genus. Some widespread northern groups, such as *Valvata* and *Anodonta* (s.s.) reach their southern limit in this region.

II. Lower Río Grande (Río Bravo del Norte) Drainage and Tamaulipas. No genera and scarcely any species are restricted to the area, outside of the Cuatro Ciénegas valley. Especially in the mussels the area marks a faunal change, for many species and genera found widely in the Mississippi Valley, and in the Gulf Coast drainage of Texas, reach their southwestern limits here. The hydrobiid snail *Cochliopina* reaches its northern limit in the lower Río Grande drainage; and the pleurocerid snail *Lithasiopsis* in Tamaulipas. So far as aquatic mollusks are known, the upper Río Grande drainage above the Big Bend resembles the closed basins to the south; it has no characteristically more southeastern or eastern species. Geological evidence (REEVES, 1965; RUHE, 1962) is consistent with this conclusion. In what is now Pecos River drainage (tributary to the Río Grande) in trans-Pecos Texas, the Hydrobiidae *Tryonia cheatumi* (PILSBRY) and "*Cochliopina*" *texana* PILSBRY mark the northeastern limit of their groups. They have no counterparts in the richer fauna of south-central Texas.

III. Río Pánuco Drainage, San Luis Potosí. Numerous species and the following genera are known only from this system:

Mussels: *Frierersonia* ORTMANN, 1912 (Elliptionidae)

Snails: *Amnipila* PILSBRY, 1956 (Thiaridae)  
*Emmericiella* PILSBRY, 1909 (Hydrobiidae)  
*Pterides* PILSBRY, 1909 (Hydrobiidae)

Like the region of the Río Grande and Tamaulipas, this region also includes some extremes of distribution: the northern limit of *Pachychilus* (Thiaridae) and *Anodontites* (Mutelidae), the southern limit of *Lithasiopsis* (Pleuroceridae) and of the Pleuroceridae as a whole. The known fauna is richer than that of the Cuatro Ciénegas valley, and the actual fauna is probably still richer on account of the greater variety of habitats and far larger area. PILSBRY (1910c) thought the Pánuco mussels were more like those to the north than to the south.

IV. Southern México. In Vera Cruz and on southward the tropical fauna becomes evident. The family Pilidae, freshwater Neritidae, *Stenophysa* (Physidae), and other groups within the Mutelidae and Thiaridae are found.

V. Valley of Cuatro Ciénegas. If one applies uniform criteria for recognizing faunal regions, then the valley of Cuatro Ciénegas forms one by itself. None of the preceding large areas has so many restricted genera.

#### Endemism of mollusks in Cuatro Ciénegas valley

The contrast between the mollusks found within, and just outside, the valley of Cuatro Ciénegas is shown in Tables 2 and 3. From these it is evident that the modern topography and drainage divides have little to do with the aquatic molluscan fauna. Before the modern irrigation canals were dug, part of the Cuatro Ciénegas valley drained into the Río Salado and thence the Río Grande (Río Bravo del Norte); there was only a trivial drainage divide between this and the areas of internal drainage. The strikingly localized fauna of the Cuatro Ciénegas area then seemingly has its roots deep in the past, and is related to ancient drainage divides or other factors causing isolation and relictual survival. Perhaps this small horseshoe-shaped valley was isolated for a long time, with

### Explanation of Plate 8

Pozos de la Becerra (Text figure 2, Locality 4),  
 14 km southwest of Cuatro Ciénegas

Figure 1: One of the spring pools at the southwest end of Pozos de la Becerra, photographed by W. L. Minckley, 28 December, 1964, when the water level was just being lowered by a newly dug canal. Water formerly flowed to the left, where bare mud is exposed, but now drains through the canal (out of sight to right). In this view the water level had dropped 46 cm from its natural level. In December 1965 the water level had dropped a total of 113 cm.

Figure 2: Underwater view in Pozos de la Becerra, showing three different snail niches. Travertine ledges (center and right) were inhabited by *Mexithauma*, perhaps being sought by the black fish (*Cichlasoma*), right center. Soft ooze (left) was habitat of *Mexipyrghus*, and the masses of *Nymphaea* (background) the habitat of *Nymphophilus*. Photographed by W. L. Minckley, December 28, 1964. In April 1965 snails were rare, and in December 1965 none at all could be found, as a result of the drastic habitat changes.





Figure 1



Figure 2



Table 2

Geographic relationships of snails from the valley of Cuatro Ciénegas. Species whose generic reference is uncertain are omitted.

Genus or Species	Distribution of Relatives
<i>Cochliopina milleri</i>	Nearest to <i>C. francesae</i> of Guatemala
<i>Coahuilix hubbsi</i>	Related genera in Texas and Alabama, U. S. A.; southeastern Europe to Caucasus Mountains, U. S. S. R.
<i>Durangonella coahuilae</i>	Other species of genus are in Valley of México, Colima, Durango, Michoacán
<i>Mexipyrghus</i> spp.	Shares features with <i>Tryonia</i> to the west, <i>Pyrgophorus</i> to the east; genus restricted to Cuatro Ciénegas valley
<i>Mexithauma quadripaludium</i>	Genus restricted to Cuatro Ciénegas valley; no close relatives
<i>Nymphophilus minckleyi</i>	Genus restricted to Cuatro Ciénegas valley; no close relatives
<i>Paludiscala caramba</i>	Genus restricted to Cuatro Ciénegas valley; even its family uncertain
<i>Assimineae</i> spec.	Mostly found along sea-coasts
<i>Physa virgata</i> GOULD	Northern México; southwestern United States including southern Plains region

only internal drainage, before the Río Salado extended its course into the area.

The antiquity of the mollusks endemic to the Cuatro Ciénegas valley is difficult to judge since the fauna of all northern México is so poorly known. If the degree of taxonomic divergence is proportional to length of isolation, as generally assumed, then the ancestral stocks of these species and genera reach deep into the Tertiary or Mesozoic. As the fauna in the region is studied perhaps it will be possible to suggest how long the valley of Cuatro Ciénegas has been separated from the adjacent bolsons and the Central Plateau.

No direct fossil evidence is available to judge the rate of evolution of the endemic genera and species, and it

Table 3

Geographic relationships of mollusks from Río Salado de los Nadadores at El Cariño, just outside the eastern edge of the valley of Cuatro Ciénegas (Text figure 2, locality 12). Note contrast with Table 2.

Species	Distribution
<i>Pisidium compressum</i> PRIME	Most of North America, from the Pacific to the Atlantic Ocean, and Canada to central México
<i>Cochliopina riograndensis</i> (PILSBRY & FERRISS)	Lower Pecos River and Rio Grande valleys, Texas; coastal plain in Tamaulipas. The locality in Coahuila is the westernmost known occurrence
<i>Gundlachia excentrica</i> (MORELET)	Southern Texas to Guatemala, in the Atlantic drainage
<i>Helisoma anceps</i> (MENKE)	Most of central and eastern North America east of the Rocky Mountains. The locality in Coahuila is the southernmost known occurrence
<i>Physa virgata</i> GOULD	Northern México; southwestern United States including southern Plains region

is unlikely that a significant fossil record of freshwater mollusks will be found in the Cuatro Ciénegas valley. The reclassification of the subfamily Littoridininae of the Hydrobiidae (see below) nevertheless provides suggestive evidence of the rate of generic divergence. Most of the genera are entirely or almost allopatric (Text figure 14), from which it seems that their taxonomic differentiation is significantly linked with geographic isolation. *Mexipyrghus*, restricted to the Cuatro Ciénegas valley, shares characters of both *Tryonia* (late Oligocene or early Miocene to Recent) and *Pyrgophorus* (early Pliocene to Recent). If one assumes that these 3 genera have diverged from a common ancestor for the same length of time, then the origin of *Mexipyrghus* goes back to early Tertiary times. Whether *Mexipyrghus* has always been restricted to the valley of Cuatro Ciénegas, or only retains part of a formerly greater distribution, is uncertain since the region is so poorly known. The possibility that there has been a freshwater habitat in the area continuously suitable for snails since middle or early Tertiary time should nevertheless be considered seriously.

The time required for the differentiation of the local forms of *Mexipyrus*, restricted to single springs or streams, can only be estimated by comparison with the rates of other hydrobiid snails. As it happens, virtually none of the living species of Littoridininae has a useful fossil record, and hence these estimates are not based on species related closely to *Mexipyrus*.

Among Hydrobiidae in the western U.S.A., *Lithoglyphus* species (Lithoglyphinae) generally have the longest range. *L. hindsii* (BAIRD) is known from a late middle Pliocene or early late Pliocene assemblage in Oregon (TAYLOR, 1966a). *Lithoglyphus columbianus* (PILSBRY) is known from the middle Pliocene, and *L. virens* (LEA) from the middle or perhaps early Pliocene (U.S. Geological Survey collections; unpublished). In correlation with this longer range the species have geographic distributions that are wider and transcurrent to the ranges of other Hydrobiidae. The one living species of Littoridininae that has been found in Tertiary rocks is *Tryonia imitator* (PILSBRY), recorded by OAKESHOTT (1958:67-68) from the upper Miocene and lower Pliocene Mint Canyon Formation in Southern California.

Other western American Hydrobiidae mostly have no fossil record, or cannot be specifically identified from their shells. The distribution of the living species is generally accordant with biogeographic patterns that seem no younger than late Pliocene in age (TAYLOR, 1966a). Judging by this analogy the localized species of *Mexipyrus* have differentiated since about the late Pliocene or earliest Pleistocene, i.e., during about 2-3 million years.

One of the more interesting biological studies possible in the valley of Cuatro Ciénegas is the comparison of rates of evolution of different animals living in substantially the same habitat: the fishes, turtles, snails, Crustacea, and so on. The mere naming and describing, let alone study, of these groups has scarcely gotten underway. The snails may prove to have the most nearly complete fossil record of these animals in the area, and hence they will be of special value in estimating rates of differentiation.

Despite the early stage of scientific study of the Cuatro Ciénegas area, there is good evidence that the habitats of the snails have been there for a long time. The speciation in *Mexipyrus* even suggests that individual large springs or groups of springs might have antiquity of a few million years. Such a length of isolation is under-

standable in an arid climate, like that of the present, but annual rainfall was almost surely substantially greater during the Pleistocene. The only area in North America where a considerable fossil record for much of this interval is available is in the southern Great Plains of the U.S.A.; there the present, living fauna is sparser than all of the fossil assemblages, and the modern semiarid climate seems to be a geologically late phenomenon (TAYLOR, 1965). If climatic change was correlative in Coahuila, then the modern arid climate might have developed only in the last 10 000-20 000 years. Nevertheless in a limestone terrain the porous soil does not retain moisture long, and even in a more humid climate the Cuatro Ciénegas valley probably had much its present surface aspect, though with increased flow of springs and streams, and increased underground flow out of the valley. This supposition is consistent with the fact that most of the unique, endemic organisms in the valley are strictly aquatic, or are marsh dwellers; and it is consistent with the evidence of the snails that their habitats have been persistent for millions of years. Surely not all the endemic species in the valley—not even the snails—have changed at the same rate, but the interpretation of evolution in fishes, reptiles, and other groups should not rest merely on the assumption of a certain rate of differentiation, nor on inferred effects of climatic change during the Pleistocene.

## LOCALITIES AND HABITATS

Descriptions of the localities and habitats, and lists of associated species, are given below. Numbers correspond to those on the locality map (Text figure 2). Four general types of habitats of freshwater mollusks have been sampled: small spring, large spring, laguna, and stream. Physico-chemical data for most of the mollusk localities cited herein are available in MINCKLEY & COLE (1966).

### SMALL SPRING (POZO)

1. Only one natural locality of this type has been sampled, a spring tributary to the area of marshes and lagunas known locally as El Mojarral, 1.7 km due east of the tip of Sierra de San Marcos, 11 km southwest of Cuatro Ciénegas; W. L. Minckley, 13-IV-1965. A bottom sam-

## Explanation of Plate 9

West Laguna in El Mojarral (Text figure 2, locality 5) 1.7 km east-northeast of the northern tip of Sierra de San Marcos. *Mexipyrus mojarralis* TAYLOR, spec. nov., is found only here. Underwater photographs by W.L. Minckley, April 1965. *Mexipyrus* lives in the soft ooze, *Nymphophilus* on the *Nymphaea* leaves. The larger fishes in both photographs are the cichlid, *Cichlasoma*.



Figure 3



Figure 4



ple of black organic ooze and abundant shells, all dead, yielded two species.

\* *Durangonella* spec.

\* R<sup>s</sup> *Paludiscala caramba* TAYLOR, gen. et spec. nov.

2. Rancho San Marcos, 20 km south-southwest of Cuatro Ciénegas. A spring here has been substantially modified for irrigation, and was not sampled. In the brief visit a collection was made from the shallow (less than 5 cm) water in the livestock-trodden muddy area around the spring. The only vegetation in these shallows was *Chara* and sedges. Snails were noticeably restricted to the marginal shallows. D. W. Taylor, 14-IV-1965.

*Physa virgata* GOULD.

### LARGE SPRING (LAGUNA)

A number of large warm springs in the valley of Cuatro Ciénegas issue through travertine-lined natural "pipes" and form pools 50-100 m in diameter, locally known as "lagunas" (Plate 8, Figure 1). The habitats in each of these are generally similar, and so are the mollusks in the 6 springs that have been examined.

Characteristically the deepest area is 5-10 m below the water surface, and most of the bottom is covered with 3-6 cm of flocculent ooze, composed mainly of snail feces, lying on a firmer substrate of shells, shell fragments, and clay. The water is clear, and only at a distance of 10-15 m does an object appear a little hazy. One who first dives in one of these large, clear lagunas with the numerous cichlid fishes (*Cichlasoma* spp.) (Plate 9, Figure 3) that are boldly colored and change color with startling speed, is immediately struck with the impression he is in an aquarium. The constant flow of water, lack of turbidity, and the virtual absence of plankton make these spring-pools conspicuously more clear than the ponds and lakes that are more nearly closed systems.

The fishes include representatives of 7 families, and at least 15 species occur in the laguna habitats of the basin. These fishes are ecologically diverse, occupying most recognized trophic levels throughout the habitat. One may surmise that this diversity in the fishes is somehow correlated with the ecologic differentiation of the snails.

Beyond a depth of 1-2 m the only conspicuous higher plant is a water-lily, *Nymphaea*. These commonly grow in patches (Plate 8, Figure 1; Plate 9, Figure 3) to a depth of several meters but beyond about 0.5 m do not send their leaves to the surface to form lily-pads. Instead the leaves remain in the juvenile, half-unrolled state at depth, and the scattered patches of lilies grow to a height of only

about 30 cm. This growth-habit of the *Nymphaea* is one of the bizarre biological aspects of the lagunas.

At a depth of less than 1-2 m the individual lagunas differ more than beyond that limit. The size and shape of each pool, and the abundance of sedges and marginal aquatic plants vary; perhaps also the pools are in different stages of ecological succession. The seasonal fluctuations in flow of the springs change the water level through a few cm, and wave action washes fine material into deeper water, so that a hard substratum (mostly tufa, sometimes rock) is exposed locally. In areas of stronger current the bottom is mainly composed of white shells and shell fragments mixed with rounded pieces of tufa, of the texture of coarse sand and fine gravel.

Three genera of snails are consistently found in all the springs, always in the same habitat. *Mexipyrus* is common to abundant in the upper 1-2 cm of the flocculent ooze bottom, in all depths of water. Presumably it digests the microorganisms (mainly bacteria?) in this material; there seems to be no other food source. The bottom is so loose in texture that at least locally these snails probably move about little if at all. They were always in the bottom, not visible at the surface.

*Nymphophilus* lives on the *Nymphaea* leaves, rarely on the lower surfaces of blocks of tufa. The rare specimens collected from the loose-textured bottom with a sieve were adjacent to *Nymphaea*, seemingly having fallen off. No *Nymphophilus* were seen on exposed surfaces: neither on the upper surfaces of submergent leaves, nor on the stems or lower surfaces of floating leaves. All collecting was done by day, hence this distribution may not be characteristic of the night. In any case it might be a consequence of fish predation on easily visible snails, rather than of food preference by the snails. Field and laboratory observations indicate *Nymphophilus* may eat the *Nymphaea* leaves themselves as well as epiphyton.

*Mexithauma* is ordinarily found on a hard substratum (stones or tufa), sometimes on a firm shelly mud bottom. Diatoms are common on the surface of its shell, whereas *Mexipyrus* shells are always completely clean, and those of *Nymphophilus* are mostly clean with some algae. Seemingly *Mexithauma* browses on algae, or eats the organic material or microorganisms in the surficial layers of mixed detritus in shallow water.

Collecting in these large springs was done manually (by picking snails off blocks of tufa, or *Nymphaea* leaves), and with sieves; both by wading in the shallower areas and diving to depths of generally 3-4 m. A fine-mesh screen (ca. 1 mm) was used briefly at most localities, but tiny snails such as *Coahuilix* were overlooked, or not found in this sampling. Hence a coarser meshed screen (ca. 2 mm) was used for nearly all bottom-sampling.

<sup>s</sup> R Species restricted to this locality

TL Type locality of species found also at other places

\* Species represented by empty shells only

The most convenient way to collect proved to be holding the screen so as to skim off the upper 1-2 cm layer of bottom while swimming. In this way large series of *Mexipyrus* were collected, but in retrospect (having discovered the *Coahuilix* specimens since the field work) rare, tiny shells would have been missed. Furthermore, I found it difficult to work for long at depths of over 6 m, and thus could not give the limey surfaces in and around the spring vents a careful search. Such places are the most likely situation in which to find traces of a special subterranean fauna, but SCUBA (self-contained underwater breathing apparatus) equipment at least will be necessary for collecting there, and still more elaborate apparatus for the subterranean conduits where no light penetrates.

In the biota of the lagunas these 3 genera of snails—*Mexipyrus*, *Mexithauma*, and *Nymphophilus*—seemingly make up the greater part of metazoan standing crop, although quantitative sampling has not yet begun. Other animal groups—for example insect larvae or adults, Crustacea, annelids, and planarians—are absent or far less conspicuous than in ponds of similar size in which I have collected in the U.S.A. Fishes are conspicuous on account of their size, and are locally numerous. So far as I can judge from a brief visit, the food chains in these lagunas are remarkably short and simple: algae and benthic microorganisms → snails → fishes. One of the cichlids is the only fish that eats snails regularly, and it is present in all the major lagunas. From the relative abundance of broken shell fragments to empty, unbroken shells in sieve samples I would guess that locally over 75% of the snails that reach maturity are eaten by fishes.

3. Laguna Churince, 16 km southwest of Cuatro Ciénegas. Water temperature ranged from 25.9-28.9°C on 6 occasions, measured by W. L. Minckley. Most collecting was done in the outflow of the spring, that is in the upper end of Río Churince (Plate 11, Figure 9). The laguna is about 50 m in diameter and contains *Nymphaea* and *Nymphophilus*, both lacking in the outflow. Río Churince here is a clear, slow stream about 2 x 0.5 m, with a soft mud bottom and the usual border of sedges. D. W. Taylor, 12-IV-1965.

R<sup>9</sup> *Mexipyrus churinceanus* TAYLOR, gen. et spec. nov.

<sup>9</sup> For explanation of symbols see footnote <sup>8</sup> above

*Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

\* cf *Succinea*

4. Pozos de la Becerra, 14 km southwest of Cuatro Ciénegas (Plate 8, Figures 1, 2). "Prior to December 1964, Pozos de la Becerra was one of the largest and most complex aquatic habitats in the Cuatro Ciénegas basin. The laguna was elongate and irregular in shape, with depths ranging to more than 10 m at the largest spring inflows. In areas of inflow the bottoms were of gravel and rubble. Other areas had bottoms of deep calcareous silt; most silt bottoms were covered by dense beds of waterlily (*Nymphaea*). The laguna originally measured about 25 m in width at its narrowest place, ranging to more than 150 m wide, and was perhaps two km long. Water was always extremely clear. Temperatures taken in the sources on seven different occasions ranged from 29.4 to 32.2°C. Water levels did not change perceptibly in the period 1960-64, and one estimate of discharge was about 1.34 m<sup>3</sup>/second at the outlet channel.

The laguna suffered some modification in 1961 through construction of a bathing facility. In 1964, however, the laguna was drastically modified by construction of a canal, and the water level fell 46 cm in about two days. In April 1965, the downcutting of the uncontrolled canal outlet had apparently stabilized, with the laguna surface lowered more than a meter. This resulted in drainage of extensive marshes that were associated with the spring, and reduced the over-all surface of water and marsh from perhaps 10 km<sup>2</sup> to less than 0.2 km<sup>2</sup>. Swimmers had muddied the laguna in April 1965, and the silty bottoms had been greatly disturbed. Many formerly gravel bottoms were silted and most of the *Nymphaea* beds were dried or uprooted. Only the inflows of the largest springs remained clear of silt" (COLE & MINCKLEY, 1966:20).

One of the drastic effects of the drop in water level was the concentration in a small volume of water of the fishes, with several-fold increase in competition for food. In April, 1965, the snails that W. L. Minckley had previously found common (*Mexipyrus*, *Mexithauma*, *Nymphophilus*) were all rare, and scarcely any of them were found alive in spite of persistent search. The snail-eating cichlids, *Cichlasoma*, were seemingly starving; they had sunk-

### Explanation of Plate 10

West Laguna in El Mojarral (Text figure 2, Locality 5), 1.7 km east-northeast of the northern tip of Sierra de San Marcos.

*Mexipyrus mojarralis* TAYLOR, spec. nov., is found only here.

Figure 5: Edge of laguna, showing juvenile *Nymphaea* and small tufa knobs in water 5-20 cm deep. *Mexithauma* was found on the lower surfaces of these tufa blocks.

Figure 6: View eastward showing most of the length of the laguna.

In the right distance is visible the western end of East Laguna to the south (type locality of *Mexipyrus multilineatus* TAYLOR, spec. nov.). Water issues from large vents out of the picture to the left; most of the water flows out through a large vent at the far end of the laguna, but there is a minor surface outflow not visible in this view. A patch of *Nymphaea* growing in about 2 m depth is at left center; a ledge of tufa in the center foreground.





Figure 5



Figure 6



en bellies. In December, 1965, thorough search by Minckley revealed no live snails.

Collections by W. L. Minckley, 28-XII-1964; D. W. Taylor, 14-IV-1965.

*Mexipyrus churinceanus* TAYLOR, gen. et spec. nov.

*Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

A sample from the surface of the marly bottom in the (former, now drained) northernmost pool was collected by C. L. Hubbs, 6-IV-1961. It yielded the preceding 3 species as well as the following:

R\* *Assiminea*

R\* *Coahuilix hubbsi* TAYLOR, gen. et spec. nov.

R\* Littoridininae, incertae sedis

R\* *Drepanotrema*?

5. West Laguna in El Mojarral, 1.7 km east-northeast of the northern tip of the Sierra de San Marcos (Plates 9, 10). The springs emerge through vents up to 1 m in diameter at the north-western end of a laguna about 25 x 100 m, up to 7 m deep. Nearly all of the water flows out through a large vent at the southeastern end of the laguna; thus there is only a trivial surface-water outflow, that runs into the next laguna (locality 6). Water temperature was 32.8°C on 2 occasions, measured by W. L. Minckley. *Nymphophilus* was sparse and small in the patches of *Nymphaea* (Plate 9) that here was less abundant than in other lagunas. *Mexithauma* was rare on the lower surfaces of tufa at the edge (Plate 10, Figure 5). *Mexipyrus* was abundant in the upper 1-2 cm of the soft, flocculent ooze bottom. D. W. Taylor, 13-IV-1965.

R *Mexipyrus mojarralis* TAYLOR, gen. et spec. nov.

*Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

6. East Laguna in El Mojarral, 1.9 km east-northeast of the northern tip of Sierra de San Marcos. The western end of this laguna receives a small surface flow from the preceding (locality 5), and can be barely seen in the right distance of Plate 10, Figure 6. The same habitats were represented here as at the preceding, nearby locality; but this laguna differs by being about 300 m long, and shallower, with much of its area 1-2 m deep, supporting scattered emergent sedges as well as *Nymphaea*. It is remarkable that the 2 nearby lagunas, only 300 m apart, with similar habitats, have obviously different forms of *Mexipyrus*. D. W. Taylor, 13-IV-1965.

R *Mexipyrus multilineatus* TAYLOR, gen. et spec. nov.

*Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

7. Laguna Escobeda, 12 km south of Cuatro Ciénegas. The spring is now only a conical pool about 20 m in diam-

eter, 10 m deep, whose natural level was evidently 2 m higher before the present outlet was dug. Water temperature was 34.4°C on the 9 occasions when measured by W. L. Minckley. *Mexipyrus* was abundant in the soft flocculent ooze of the bottom, and was the only snail found alive. White, empty shells of *Mexithauma* and *Nymphophilus* are common in the spring flow, but *Mexipyrus* is the only snail living there. Aquatic vegetation is almost nil; no *Nymphaea* remains; fish are scarce. Clearly the biological diversity and productivity of the laguna have been drastically reduced, by the elimination of large areas of shallow, vegetated water. W. L. Minckley, 31-XII-1964; D. W. Taylor, 15-IV-1965.

R *Mexipyrus escobedae* TAYLOR, gen. et spec. nov.

\* *Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

\* *Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

8. Laguna Tío Cándido, 14 km south of Cuatro Ciénegas. The laguna is 250-300 m long, and up to 4 m deep. Water temperature at the surface ranged from 21.1 to 27.8°C on four occasions when measured by W. L. Minckley. Irrigation development has lowered the water level slightly, but seemingly there have been no drastic changes in the snail fauna since the 3 characteristic genera are present. The bottom is more thickly vegetated with *Nymphaea* than other lagunas, and both *Nymphaea* and sedges can be seen at the surface around the edges (Plate 12, Figure 9). *Mexipyrus* was in the soft mud bottom, as elsewhere. *Nymphophilus* was regularly on the under side of *Nymphaea* leaves, and also on the lower surfaces of tufa and stones with an epiphyton. *Mexithauma* was mostly on stones or a firm substratum covered with a thin (about 1 cm) layer of mud, so that the snails were invisible; but rarely they were on *Nymphaea* too. D. W. Taylor, 15-IV-1965.

This is the type locality of the turtle *Trionyx ater* WEBB & LEGLER (1960).

R *Mexipyrus carranzae* TAYLOR, gen. et spec. nov.

TL *Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

## LAGUNA

Two localities are in what an English-speaking American would call ponds or lakes, but locally they are called lagunas like the preceding group of large spring sources.

9. Unnamed laguna about 1.0 km northwest of Laguna Churince, 16 km south-southwest of Cuatro Ciénegas. The laguna is about 250 m long, 65 m wide, with a soft calcareous ooze bottom and pebble to cobble-sized discoidal to irregular blocks of tufa at the actively eroding edge.

Cattails (*Typha*) grew in protected places, sedges around the edge. *Nymphophilus* was sparse on the lower surfaces of tufa blocks, and another hydrobiid rare. The habitat was similar to that at the edge of West Laguna in El Mojarral (Plate 10, Figure 5), but no *Nymphaea* was found. D. W. Taylor, 14-IV-1965. The banks had been eroded about 12-18 m locally by December, 1965, according to observations by W. L. Minckley.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

Hydrobiidae, incertae sedis

10. Laguna Grande, at mouth of Río Churince, about 17 km southwest of Cuatro Ciénegas. This laguna is the sump of Río Churince and has no surface outlet. It is about 2 km long, 1 km wide, with a high magnesium chloride content and dunes of nearly pure gypsum on the west. At the mouth of the river, in the middle of the east side of the laguna, the *Scirpus* bordering the stream extended a little way into the laguna but elsewhere the only vegetation was isolated individuals of a tiny *Chara*, only about 3 cm high. Along the edges of the laguna at a depth of less than 20 cm clumps of grasses formed islands 2-3 m in diameter. The bottom was soft mud in the upper 5-10 mm of which *Durangonella* was common. The specimens collected came from a depth of about 5-30 cm, but the snails might occur throughout the laguna. No *Durangonella* were found within about 4-5 m of the mouth of Río Churince, either because of lowered salinity or a combination of factors. D. W. Taylor, 14-IV-1965.

The species described from this laguna is probably re-

stricted to it, but the anatomy of *Durangonella* from elsewhere in the valley is unknown.

R *Durangonella coahuilae* TAYLOR, spec. nov.

### STREAM

11. Río Mesquites 9 km southwest of Cuatro Ciénegas, at the road running from Cuatro Ciénegas around the northern end of Sierra de San Marcos (Plate 11, Fig. 8). The habitat is much like that in the outflow of Laguna Churince; see explanation of Plate 11 for comparison of these 2 localities. The stream is generally about 2 m wide, 1-1.5 m deep, flowing between steep banks with a clear, steady current. *Cochliopina* was mostly in the soft mud of backwaters where it was associated with *Mexipyrus*; the latter was also in the main stream where *Cochliopina* was absent. *Nymphophilus* was common on the lower surfaces of the submerged clusters of *Nymphaea* leaves, as in the lagunas. The bottom of soft mud and gravel with scattered stones and dead wood gave the habitat the appearance of being much like those found widely in the U.S.A., but lacked mollusks that one would expect. There were no Sphaeriidae, Lymnaeidae, or Planorbidae found in spite of search for them. The species represented by empty shells only are known by single specimens in each case. D. W. Taylor, 13-IV-1965.

R *Cochliopina milleri* TAYLOR, spec. nov.

\* *Durangonella*

\* Hydrobiidae, incertae sedis

R *Mexipyrus lugoi* TAYLOR, spec. nov.

### Explanation of Plate 11

Río Churince and Río Mesquites

The localities are about 12 km apart, and look similar on the ground as well as in these illustrations. Yet they have no species in common. Figure 7: Río Churince at its source about 20 m downstream from Laguna Churince (Text figure 2, Locality 3), 16 km southwest of Cuatro Ciénegas. View northwestward toward Laguna Grande (not visible). About 0.5 km in the distance is an intermediate laguna (Text figure 2, Locality 9) also not visible in this view, where *Nymphophilus* was collected. In the short segment of Río Churince shown here *Mexipyrus churinceanus* TAYLOR, spec. nov., was abundant in the muddy bottom; *Mexithauma* was common on the firmer parts of the bottom and on the steep walls of the stream. *Nymphophilus* was found living in the laguna upstream, but not

here. Water depth about 0.5 m.

Figure 8: Río Mesquites (Text figure 2, Locality 11), 9 km southwest of Cuatro Ciénegas. The road crosses the stream at the right (just out of the picture) and runs south-southwest around the northern end of Sierra de San Marcos (center skyline). Río Mesquites has greater flow than Río Churince, with more rapid current, and is deeper (0.5 - 1.0 m). *Nymphaea* grows here in submerged masses as in the lagunas. The fauna differs from that found above (Figure 7) by having *Cochliopina*, *Nymphophilus*, and a different *Mexipyrus* (*M. lugoi* TAYLOR, spec. nov.); and by lacking *Mexithauma*.

### Explanation of Plate 12

View southeastward across Laguna Tío Candido (Text figure 2, Locality 8), 14 km south of Cuatro Ciénegas.

Eastern slope of Sierra de San Marcos at right. Water depth 3 - 4 m. Floating pads of *Nymphaea* and emergent sedges are visible toward the edges in shallower water. Type locality of *Mexithauma quadri-paludium* TAYLOR, gen. et spec. nov.; and *Mexipyrus carranzae* TAYLOR, gen. et spec. nov.

Figure 10: Río Salado de los Nadadores at El Cariño de la Montaña (Text figure 2, Locality 12), 20 km east of Cuatro Ciéne-

gas. The locality is just outside the northeastern edge of the valley of Cuatro Ciénegas, in a stream naturally tributary to the Río Grande (Río Bravo del Norte). The fauna is entirely like that of the Río Grande drainage; none of the new local species of the Cuatro Ciénegas area was found here. *Helisoma anceps* was found only in the small spring pool in the center foreground; the other species were both in the spring and in sheltered situations along the edge of the stream.



Figure 7



Figure 8





Figure 9

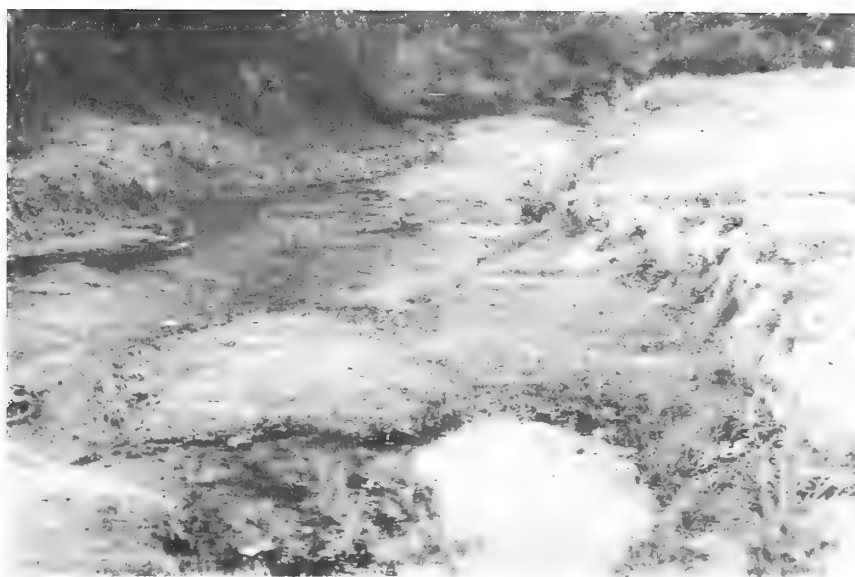


Figure 10





TL *Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

\* *Physa virgata* GOULD

12. Río Salado de los Nadadores at El Cariño de la Montaña, 20 km east of Cuatro Ciénegas. The locality is on the main road from Monclova to Cuatro Ciénegas where the river (here nearly at its head) is narrowly hemmed by the mountain ridge forming the eastern edge of the valley of Cuatro Ciénegas. Mollusks were collected from within a radius of about 4 m, in a spring beside the river and in a protected spot along the edge of the stream (Plate 12, Fig. 10). The spring forms a pool about 6 m long, with a bottom of fine sand and silt overlain by algae and with scattered *Potamogeton*. *Cochliopina* and *Pisidium* were sparse in the bottom of the pool, *Physa* and *Helisoma* common. Along the edge of the stream, in fine mud among watercress, *Cochliopina* and *Pisidium* were common. D. W. Taylor, 12-IV-1965.

*Pisidium compressum* PRIME

*Cochliopina riograndensis* (PILSBRY & FERRISS)

*Gundlachia excentrica* (MORELET)

*Helisoma anceps* (MENKE)

*Physa virgata* GOULD

## SYSTEMATIC DISCUSSION

### Previous Work

Virtually no freshwater mollusks have been collected previously in the arid interior of northern México, the Altiplanicie Septentrional. The indispensable summary by VON MARTENS (1890-1901) lists only 1 from Coahuila. I have been able to find only 5 published records from the state: *Lampsilis salinasensis* SIMPSON (in DALL, 1908); *Friersonia iridella* (PILSBRY & FRIERSON) (DRAKE, 1951); *Limnaea desidiosa* SAY (PILSBRY, 1904); *Physa osculans rhyssa* PILSBRY (1899c); and *Physa berendti* DUNKER (DALL, 1905). Edward Palmer, of the U.S. Department of Agriculture, traveled extensively in México in collecting plants. According to DALL (1905:193) he "collected a considerable number" of mollusks that have not been recorded; perhaps other material from Coahuila is among that in the U.S. National Museum collections. Another record from Coahuila (*Sphaerium transversum*) has been added from University of Michigan collections.

The following abbreviations have been used:

M.	Monotypy
O.D.	Original designation
S.D.	Subsequent designation
UMMZ	University of Michigan Museum of Zoology
USNM	U.S. National Museum

## PELECYPODA

### SCHIZODONTA

#### UNIONACEA

##### ELLIPTIONIDAE

The basic reference to freshwater mussels is the catalogue by SIMPSON (1914). This work gives descriptions and general ranges of all species, but the classification has been modified subsequently. Studies by ORTMANN (1912 and others) have led to the classification summarized by WALKER (1918), which is the one generally in use in America. Mexican species (not listed by WALKER) have been summarized by FRIERSON (1927). The more finely dividing classification by MODELL (1964), adopted here, includes data on distribution at the generic level.

#### Lampsilinae

*Actinonaias* CROSSE & FISCHER, 1894

(*Disconaias*) CROSSE & FISCHER, 1894

The species within the subgenus were listed by FRIERSON (1927), who recognized 8 forms. According to MODELL (1964:95), its distribution is from northeastern México south to northern Guatemala.

*Actinonaias (Disconaias) fimbriata* (FRIERSON, 1907)

This species has been recorded previously from Coahuila as *Lampsilis salinasensis* SIMPSON (in DALL, 1908), a synonym of *Actinonaias fimbriata* according to PILSBRY (1910c), ORTMANN (1912), SIMPSON (1914), and later writers. The type locality of *L. salinasensis* was given as "Salinas River, Coahuila, México, Nelson and Goldman," but most likely it is the Río Sabinas at Sabinas, Coahuila.

The summary of Nelson and Goldman's expeditions in México (GOLDMAN, 1951) mentions no Salinas River in Coahuila, but records that they spent 10 days at Sabinas, on the Río Sabinas, from May 20 to 31, 1902. DALL (1908:177) specified that the material was collected by Nelson and Goldman in 1898, but during that year they were not in Coahuila at all (GOLDMAN, 1951).

Other localities for the species include Río Valles, San Luis Potosí, the type locality; Playa de Misantla, Vera Cruz (MARTENS, 1890-1901, pl. 37, fig. 3, reidentified by FRIERSON, 1927); and Río San Juan, Vera Cruz (H. B. BAKER, 1922:20, as *Actinonaias walkeri*, a synonym of *A. fimbriata* according to FRIERSON, 1927).

*Friersonia* ORTMANN, 1912

*Friersonia iridella* (PILSBRY & FRIERSON, 1908)

This species has been found living only in the Río Pánuco drainage of San Luis Potosí (PILSBRY, 1910c), but DRAKE (1951) recorded it from an archeological site, C68, in Coahuila. The location of the cave on the eastern edge of the Cuatro Ciénegas basin has been recorded by GILMORE (1947). This clam cannot surely be considered

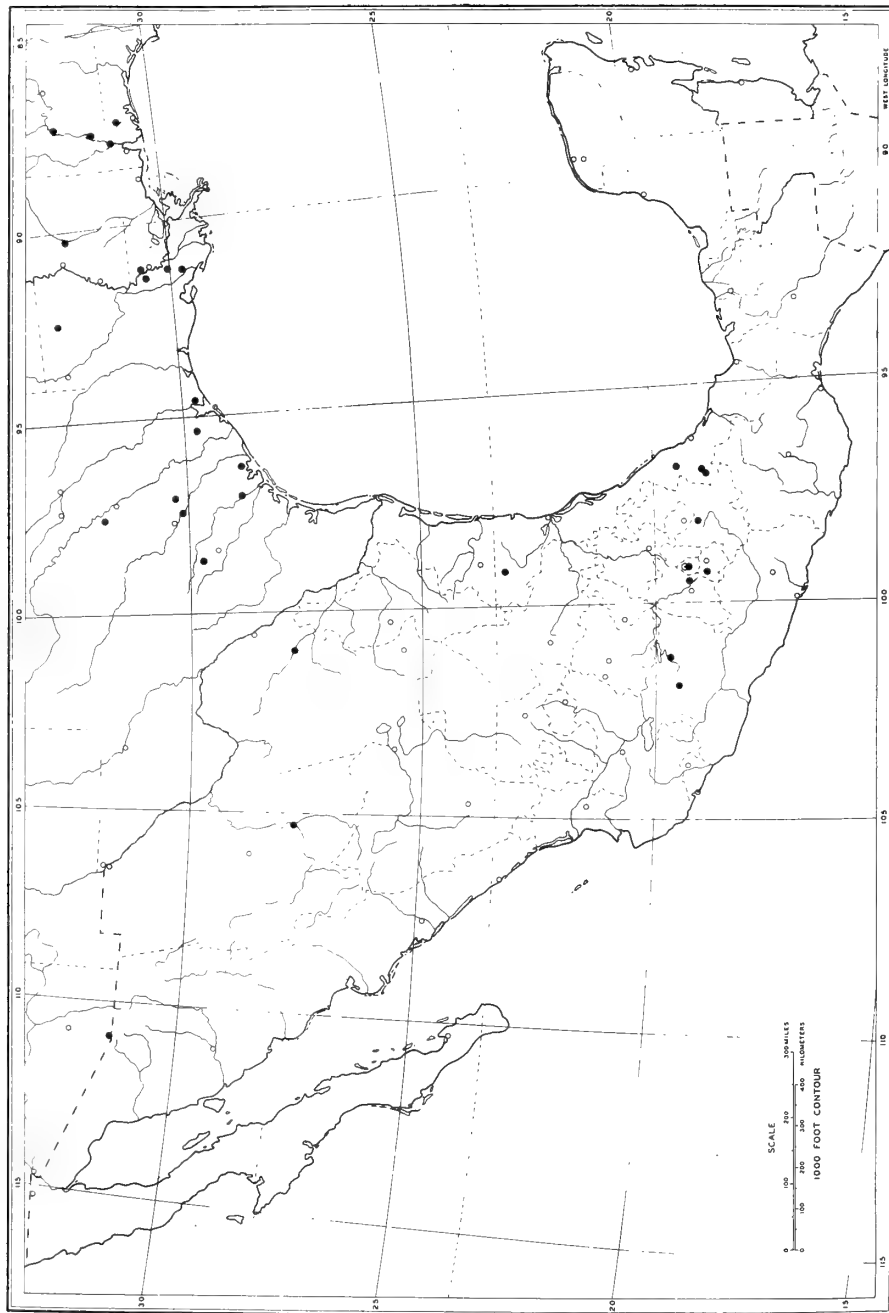


Figure 3  
Distribution of *Sphaerium transversum* (Say) in México and southern United States.

part of the modern local fauna without verification, since the shells might have been carried some distance by the Indians.

## HETERODONTA

### CORBICULACEA

#### SPHAERIIDAE

The most recent review of this group in North America is by HERRINGTON (1962), whose work provides taxonomic revision, entrance to the literature, and data of general geographic distribution. HEARD (1966) summarized some later modifications in the classification of *Pisidium*.

*Sphaerium* SCOPOLI, 1777

*Sphaerium transversum* (SAY, 1829)

In North America this species is found widely east of the continental divide, from Canada southward to central México. Specimens in the University of Michigan Museum of Zoology come from the following localities in northeastern México:

CHIHUAHUA. Slough into Río Conchos (no more precise data); R. J. Drake, 12-VIII-1947 (UMMZ 199895).

COAHUILA. Río Sabinas, Sabinas; Leslie Hubricht, 6-III-1955 (UMMZ 199290).

TAMAULIPAS. Lake at Joya de Salas, 14 miles northwest of Gómez Farías; Rez Darnell, 10-IV-1951 (UMMZ 191838).

The distribution map (Text fig. 3) has been compiled from published records and specimens examined personally. Occurrences in México are based on collections of the U.S. National Museum, University of Michigan Museum of Zoology, and records by MARTENS (1890-1901) and PILSBRY (1904). The record in Arizona is from TAYLOR (1966b); and those elsewhere in the United States from HEARD (1963). The map shows how far the newly reported occurrences in northern México go towards filling in the gap between central México and Texas.

*Pisidium* C. PFEIFFER, 1821

(*Rivulina*) CLESSIN, 1873

*Pisidium (Rivulina) compressum* PRIME, 1851

This small clam is one of the most widespread freshwater mollusks in North America, found from Alaska to México. Specimens in the University of Michigan Museum of Zoology come from the following localities in northeastern México:

CHIHUAHUA. Salaires; R. J. Drake, 21-IV-1948 (UMMZ 199523). Laguna Toronto; R. J. Drake, 6-X-1947 (UMMZ 199521).

COAHUILA. Río Salado de los Nadadores, El Cariño, 20 km east of Cuatro Ciénegas; D. W. Taylor, 12-IV-1965 (UMMZ 220144).

TAMAULIPAS. Lake at Joya de Salas, 14 miles northwest of Gómez Farías; Rez Darnell, 10-IV-1951 (UMMZ 199550).

The adult specimens from Coahuila are typical, with coarse striae and a dull shell. The half-grown ones associated are less typical in having few coarse striae, mostly fine striae, broader beaks than commonly found in the species, and a less dull shell. Features of the hinge and outline are so similar that no separation is warranted, and the differences from usual *Pisidium compressum* can be attributed to habitat or to variation toward the southern limit of range of the species. H. B. Herrington corroborated the identification of the species.

## GASTROPODA

### MESOGASTROPODA

#### RISSEOACEA

##### HYDROBIIDAE

Study of the hydrobiid snails from the valley of Cuatro Ciénegas soon revealed the paltry knowledge of this family. Although the species of *Mexipyrghus* seem clearly related to *Tryonia* and *Pyrgophorus*, and fall within the framework of previous classification, the other genera (*Coahuilix*, *Mexithauma*, *Nymphophilus*, *Paludiscala*) do not. The most recent summary of Hydrobiidae is that by WENZ (1938-1944); it is mainly founded on the studies by THIELE (1928). An appraisal of these novel genera from México has thus required not only the compilation of subsequent information, but also the revision and application of new diagnostic characters for many groups within the Hydrobiidae. Accordingly I have reviewed all the freshwater Rissoacea of the Western Hemisphere, and established new diagnoses for the Hydrobiidae and the subfamilies that occur in North America. Tropical American genera that seem to belong in these groups have been so allocated, but the South American groups that are obviously different (for example, *Potamolithus*) are not dealt with at all.

Two large subfamilies that occur in the valley of Cuatro Ciénegas are the Littoridininae and Cochliopinae. Most or all of their species occurring in the Western Hemisphere have been listed, but the other subfamilies have not been dealt with in such detail. A large proportion of the Central American Hydrobiidae cannot be allocated to genus or subfamily on the basis of shell alone. They will remain *incertae sedis* until someone can study them from preserved or preferably living material.

An outgrowth of this and earlier studies of Hydrobiidae is the conclusion that the Bithyniidae are not closely re-

lated, and are more appropriately classified in the Viviparacea. The weighty differences between Hydrobiidae and Bithyniidae have been outlined in the diagnosis and comparisons below: they include features of average body size; operculum (both composition and mode of growth); form of tentacles; pattern of pigmentation; presence of the ciliary feeding apparatus including epitaeia, food-groove, numerous long ctenidial lamellae, and siphon; nuchal lobes; innervation and inferred homology of penis; mode of egg-laying and structure of egg-capsules; shape and structure of fecal pellets; and sperm dimorphism. Classifying the Bithyniidae in the Rissoacea alongside the Hydrobiidae (WENZ, 1938-1944) seems to obscure the relationships of both groups more than it reveals them. Ranking Bithyniidae as a subfamily within Hydrobiidae (THIELE, 1928; MORRISON, 1949) has even less to commend it.

This reclassification of Bithyniidae is of considerable pertinence to the subdivision of Hydrobiidae, for it calls into question the taxonomic value (at this level) of the radula. The classification by THIELE (1928) seems to overemphasize the significance of radular features in Bithyniidae. Similarly it appears that the Delavayidae (classified by Thiele in the Lithoglyphinae of the Hydrobiidae) are more like Cerithiacea than Hydrobiidae, despite some radular features (TAYLOR, 1966a). For these reasons I have not relied on radular characters in diagnosing groups within Hydrobiidae; the correlation of sets of morphological features with details of radular structure will be the surest test of usefulness of the latter. At the level of genus, and often species, the systematic value of the radula has long been established; but at least among the lower Mesogastropoda one may doubt whether the radula shows relationships between families. The acquisition of basal denticles on the central tooth, the modifications in shape and number of cusps, the appearance of glabella and supporting arch, all seem likely to be correlated with similar adaptations in feeding. From a simple radula as in Viviparidae (among the most primitive Mesogastropoda, species of which feed on fine particulate matter by picking it up with the radula, or by a ciliary apparatus), to a more complex radula with interlocking structures and stronger cusps for browsing and rasping, seems likely to be a change that took place independently in several groups.

#### DIAGNOSIS OF HYDROBIIDAE

The following diagnosis is based on published literature and on personal observations, with profitable influence from discussions with G. M. Davis and W. O. Gregg. It is based mainly on study of American species, but is in-

tended to cover the family as a whole. Characters common to Rissoacea generally have been omitted except to emphasize relationships.

**Shell:** The shell is minute to small, 1 to 6 mm, rarely over 10 mm. It is planispiral to aciculate, with about 2-8 whorls, coiled dextrally, phaneromphalous to cryptomphalous. The last whorl may be lax; rarely even most of the shell forms a loose corkscrew. The calcareous part of the shell has no color pattern, although the periostracum may. The aperture may be thickened within, or sinuous, or deflected, or flared; but there are no notches, canals, or siphonal grooves. In most genera the shell is smooth except for fine, collabral growth lines; the exceptions are the occurrence of one to a few spiral carinae (as in *Pyrgulopsis* or *Limnothauma*), or blunt calcareous spines (as in *Pyrgophorus*), or low axial ribs or reticulate sculpture (as in *Tryonia*), or fine riblets (as in *Coahuilix*), or numerous spiral cords (as in *Cochliopina* and *Mexithauma*). Elaborate sculpture (except in *Ohrigocea*) and apertural denticulations are unknown. The periostracum is smooth (except for the series of bristles in *Mexithauma*; and in *Potamopyrgus* there may be short periostracal spines on the shoulder, much as in species of *Thiara*). Internally the shell is simple; plications or lamellae are unknown. The apex may be eroded, but is not deciduous, and the tip of the spire is not plugged internally.

**Operculum:** The operculum is corneous and lacks an internal process or callus; mostly it is paucispiral, rarely multispiral. In a few genera the operculum is in the shape of a hollow cone, with the outer edge of the whorl forming a spiral flange.

**Head-foot mass:** The foot is strong and mobile, retractile into the shell, truncate in front, rounded behind, with the anterior corners produced into auriculate lobes. There are no tentacles or lobes on its sides or hind end. The only structure associated with mucus glands is an anterior transverse pedal groove, into which the anterior mucus glands empty as in many other families.

The tentacles are filiform, with blunt or rounded tips, mostly circular in cross-section, rarely oval (*Amnicola*). The eyes are usually in discrete swellings on the lateral bases; but may be at the distal end of broad tentacular bases, or sunk into a stout, tapering tentacle with no swelling visible (Lithoglyphinae). Usually the tentacles are symmetrical; in *Clenchiella* the left tentacle is laterally serrate toward the base. Cilia on the tentacles may be evenly distributed, or in discrete tracts, but are vibratile and uniform in length (except *Hydrobia*).

**Radula:** The central tooth has 1-4 basal denticles on each side.

**Pigmentation:** Pigmentation is due to a suffusion of fine melanin granules that may give a color ranging from pale

gray through dark gray to purplish, depending on intensity. Only melanin is known, except in *Lithoglyphinae*, which also have larger yellow pigment granules. On the external head-foot the pattern of coloration is usually in bold, diffuse-edged shapes; the tentacles may have short, transverse bars of melanin. White or yellowish hyaline granules are concentrated behind and medial to the eyes, giving the appearance of eyebrows, or rarely distal to the eyes. A few genera, mainly those of subterranean habitat, lack all pigment.

**Mantle and cavity:** The mantle border is smooth (except that *Mexithauma* has low swellings); a pallial tentacle is unknown (except *Hydrobia*), and no siphons are present. The floor of the mantle cavity is smooth, lacking epitaenia and food-groove. Both ctenidium (formed of about 10-60 triangular lamellae) and osphradium are present. The male reproductive organ is attached to the floor of the mantle cavity; the attachment varies from a little to the left of the mid-line to a sagittal plane through the base of the right tentacle. This organ, the verge, may be a simple penis as in marine Rissoacea, but more often it has large accessory glandular processes, and may have 1 or 2 ducts in addition to the vas deferens. The tip of the verge may or may not be ciliated more strongly than the rest. The oviduct courses parallel to the rectum and opens beside it (except in *Mexithauma*).

**Reproduction:** Hydrobiidae are rarely parthenogenetic (*Potamopyrgus jenkinsi*), sometimes ovoviviparous, and usually oviparous. A free veliger stage is known only in *Hydrobia ulvae*. The eggs are laid singly in capsules, either appressed to some firm surface or loose in the substratum (except *Hydrobia ulvae*, which lays several eggs per capsule).

**Habitat:** Nearly all Hydrobiidae are freshwater snails. Some are brackish-water, none strictly marine. The rare terrestrial species are all in the Pomatiopsinae.

**Fecal pellets:** Fecal pellets of Hydrobiidae are as in typical Rissoacea. They are elliptical in plan, circular in cross-section, about 2 to 2½ times as long as wide, and non-spiral. No regular arrangement of constituent matter, nor marks of a typhlosole, are evident.

**Feeding:** All Hydrobiidae are browsers. They may select fine particulate matter, or rasp diatoms and other micro-organisms from firm surfaces, or eat small animals that are injured or freshly dead. They do not have a ciliary mechanism for feeding.

**Other features:** The verge is of pedal origin. Sperm dimorphism is unknown. Fertilization is internal, and copulation seemingly the rule. A crystalline style is known (or presumed) to be present in all species. Spermatozoa are all of 1 type, cupyrene.

**Comparison of shell:** Many or most Bithyniidae attain a size over 10 mm; their size thus seems to be significant, as it is correlated with other differentia.

The nearly straight or largely uncoiled shells of Caecidae, Ctiloceratidae, and Orygoceratidae have no parallel in Hydrobiidae. *Liobaicalia* (Baicaliidae) is a close parallel to *Ecpomastrium* (Hydrobiidae, Littoridininae) in being coiled loosely like a corkscrew.

Color pattern in the shell differentiates some species of *Pliopholys* (Pliopholygidae) from *Lithoglyphus* (Hydrobiidae) to which they are otherwise similar. The Bithyniidae also lack color pattern, and so differ from other Viviparacea (Viviparidae, Pilidae, Pliopholygidae). Color pattern in marine Rissoacea has not been studied, but in the light of my experience should yield useful characters.

An anterior siphonal notch is present in some marine Rissoacea; this feature is not known in Hydrobiidae. A posterior siphonal trace can be seen as a depression at the posterior corner of the aperture in some species of *Tylopoema* (Bithyniidae) and *Pliopholys* (Pliopholygidae). This depression is interpreted as a correlative of an exhalant siphon as in *Bithynia*. No Hydrobiidae have exhalant or inhalant siphons.

Sculpture in Hydrobiidae, though generally weak, shows a wide range of variation. On the average, the Micromelaniidae are more elaborately sculptured: reticulate sculpture, axial ribs, and multiple carinae are more common. The similarity in turritiform shape and relatively complex sculpture between Micromelaniidae and some Littoridininae (Hydrobiidae) raises the question whether these features may not be inherited from their common ancestry.

The smooth periostracum is a character that has not been widely used previously, but seems to be useful. *Antroselates* might be the only American hydrobiid with periostracal sculpture, but it was described as lacking basal denticles on the central tooth. The association of these 2 features strengthens my belief that this snail is not hydrobiid and favors the idea the periostracal characters may be more useful than appreciated previously. *Mexithauma*, here referred to the Hydrobiidae, is unique in its spiral series of short bristles of periostracum.

The Truncatellidae characteristically have a shell with the apex broken off, and the opening in the spire plugged. A similar, perhaps homologous, feature is known in Caecidae. The nearest approach in the Hydrobiidae is the progressive filling of the spire to keep pace with erosion.

**Comparison of operculum:** The Bithyniidae uniformly have a calcareous operculum with paucispiral nucleus and concentric edges. Neither feature is known in Hydrobiidae, but can be duplicated in Viviparacea. Both Viviparidae

and Pilidae have concentric opercula, and in some Pilidae the operculum bears an internal calcareous pad.

*Brachypyrulina* (Hydrobiidae, Littoridininae) is the only hydrobiid with an internal reinforcement to the operculum; it has an internal, subspiral, corneous thickening. The internal process of the operculum in Rissoiidae, the internal lamellae of Stenothyridae, and the external calcareous pad of some Truncatellidae, have no counterparts in Hydrobiidae.

The remarkable corkscrew-like operculum of some Hydrobiidae appears to be an independent development in otherwise dissimilar groups. It is known in *Rhampophoma* and *Strombopoma* (Littoridininae), and *Gocea* (Cochliopinae; see HADŽIŠČE, 1956a).

**Comparison of head-foot mass:** The nuchal lobes found in Bithyniidae and other Viviparacea are unknown in Hydrobiidae. A short pedal tentacle, a posteriorly divided foot, and a posterior mucus gland occur in some marine Rissoiidae; none of these are known in Hydrobiidae.

The tentacles are relatively longer, more flexible, and more acute in Bithyniidae than in Hydrobiidae; in this respect they are intermediate between Hydrobiidae and Pilidae, but more like Hydrobiidae than Viviparidae. In some marine Rissoacea (Rissoiidae, Vitrinellidae, Caecidae) there may be a group of stiff, longer bristles on the tips of the tentacles; perhaps these occur in some brackish-water Hydrobiidae, but not in those of fresh water that I have seen. *Pyrgophorus* (Littoridininae) might be the only hydrobiid in which one tentacle is markedly longer than the other, but the observations (GUILDING, 1828) need confirmation. In *Hydrobia* ciliation of the left tentacle may be greater than on the right, and there are both vibratile and non-vibratile cilia (FRETTER & GRAHAM, 1962). These features, together with the short pallial tentacle known only in *Hydrobia* among all Hydrobiidae, link *Hydrobia* to the marine Rissoiidae.

**Comparison of radula:** *Bithynia* may have more than 4 basal denticles on each side of the central tooth (up to 6), but otherwise the radula is more like that of Hydrobiidae than other groups. In the well-studied Balkan Pyrgulinae (RADOMAN, 1955) the central tooth lacks basal denticles and hence the group is excluded here from the Hydrobiidae, and referred to the Micromelaniidae following HADŽIŠČE (1956b).

**Comparison of pigmentation:** Pigmentation is a valuable source of characters, but has been rarely studied. Melanin is retained by snails in alcohol, but other features mentioned soon vanish, and therefore must be studied in life.

Pattern of pigmentation in Viviparacea is distinctive: yellow or orange pigment granules occur in discrete or partly fused aggregations that form irregular splotches of color. The pigmentation of Bithyniidae is entirely like

that of Viviparidae and Pilidae, and entirely unlike that of Hydrobiidae. *Lithoglyphus* is the only hydrobiid I have seen that has any pigment other than melanin. Yellow granules occur in its body in the diffusely scattered pattern in which melanin is arranged in other genera.

**Comparison of mantle and cavity:** An epitaenia and associated food-groove are found in Bithyniidae and Viviparidae; an epitaenia alone in Pilidae. These features in Bithyniidae are functionally correlated with a number of ctenidial leaflets greater than that known in any Hydrobiidae.

A verge with more than 1 duct is known only in Bithyniidae besides Hydrobiidae. The homology of these structures is doubtful, since the innervation is different in the two groups.

At least in part, the glandular accessory processes of the verge in Hydrobiidae of fresh waters may be an ecological adaptation. That they are not entirely so is shown by the genera that have no accessory processes.

In *Mexithauma* the mantle border is not smooth, but papillose; and the oviduct is bent sharply through more than 90° in its final course, opening on the floor of the mantle cavity.

**Comparison of reproduction:** The eggs of *Bithynia* are laid in 2 or 3 rows, with 1 egg per capsule, each capsule alternating with adjacent ones. The number of capsules in each mass is commonly 10 to several tens; each capsule has a plug in its dorsal surface (FRETTER & GRAHAM, 1962). The deposition of numerous capsules, and the plug in each one, are features unknown in Hydrobiidae. Neither are these features specially like Viviparacea, of which the Viviparidae are ovoviviparous, and the Pilidae lay clutches of spherical calcareous eggs.

Several characters of *Hydrobia ulvae* are more reminiscent of Rissoiidae than of other Hydrobiidae. Such are the free veliger stage, multiple eggs per capsule, brackish-water habitat, and pallial tentacle. Some of these may be associated with adaptation to the habitat, but collectively they suggest this species is an annectant form close to the common ancestry of both Rissoiidae and Hydrobiidae. Though inconvenient to those writing diagnoses, such forms have the valuable function of reminding one that higher classification is often arbitrary.

**Comparison of fecal pellets:** ARAKAWA (1962, 1963, 1965) has demonstrated a considerable variety of taxonomically useful characters in molluscan feces. Stimulated by his first paper I began to observe representatives of various families and genera as occasion permitted. An unexpected discovery was the strikingly different shape and construction of fecal pellets in Bithyniidae and Hydrobiidae. In Bithyniidae (*Bithynia* and *Parafossarulus*) they are narrowly elongate, cigar-shaped, and of spiral con-

struction. Those of Hydrobiidae are ovoid and non-spiral, reflecting a fundamentally different mode of formation. Fecal pellets of Pilidae and Viviparidae (Viviparacea) that I have examined are likewise built spirally, but are not as elongate. The spiral mode of formation is rarely evident from shape of the pellets. It can be seen by the contrast in color of the constituent particles, but may be obscured by relatively large grains of silt or fine sand. In studying *Bithynia* I found it convenient to let the snails feed on chalk, after which they produced fecal pellets of fine, even texture that were clearly spiral. The fecal pellets of Hydrobiidae I have examined are uniformly elliptical in plan, with bluntly rounded ends and circular cross-section. Genera examined are *Amnicola* (Amnicolinae), *Lithoglyphus* (Lithoglyphinae), *Pomatiopsis* (Pomatiopsinae), *Tryonia* and *Mexipyrgeus* (Littoridininae), and several Hydrobiinae.

**Comparison of feeding:** All Bithyniidae studied are able to collect particulate matter with the ctenidium, and pass it along the food-groove to the mouth. The extent to which this is an optional or obligatory mechanism in the family is unknown; but no Hydrobiidae can feed this way. The marine snails that are ciliary feeders are all in groups other than Rissoacea.

**Comparison of other features:** Few snails are thoroughly known in even gross morphology, so remaining characters are limited by the state of knowledge. Sperm dimorphism is known in Bithyniidae and Viviparidae, but not in Hydrobiidae. The innervation of the penis in *Bithynia* is pallial, a character showing affinity to the Pilidae (Viviparacea), which have a pallial penis.

#### Genera described as Hydrobiidae here excluded

The genera mentioned below were first described as Hydrobiidae, and are surely closely related to the family. The criteria that seem most useful to me enjoin classification in different families. The gradual accumulation of knowledge will reveal whether the differentia and the ranks of these other groups have continued usefulness.

*Antroselates* HUBRICHT, 1963, was described as lacking basal denticles on the central tooth of the radula. Accordingly it is not hydrobiid; I suggest it may be an American representative of the Micromelaniidae, Emmericiinae.

*Rachipteron* THOMPSON, 1964, is most likely one of the Rissoidae in the broad sense of COAN (1964), but might be included in the Stenothyridae even if that group is separated from the Rissoidae. The characters that seem distinctly non-hydrobiid are the lanceolate (rather than broadly rounded) hind end of the foot; and the spine in the tip of the penis. The simple, bifurcate penis and the

numerous spiral cords on the shell are also distinctive, but in themselves would not indicate affinity outside of the Hydrobiidae.

The criteria THOMPSON (1964) used for classifying *Rachipteron* in the Hydrobiidae rather than Rissoidae were the lack of pallial tentacles, and the presence of basal denticles on the central tooth. One of the criteria ANNANDALE & PRASHAD (1921) used to define the Stenothyridae was the presence of basal denticles, and so far as one can tell from their descriptions and illustration they saw no pallial tentacles in the species examined. They did not illustrate the penis but described it as simple, with no lateral process. The foot of the species illustrated is pointed behind. As illustrated by ABBOTT (1951) *Stenothyra* has a verge with no accessory processes, but with a terminal spine; it has a central radular tooth with basal denticles, and lacks pallial tentacles. Obvious differences from *Rachipteron* are the presence of chitinous lamellae on the inside of the operculum, and a posterior pedal tentacle. ABBOTT classified *Stenothyra* in the Rissoidae. While I do not suggest *Rachipteron* is closely related to *Stenothyra*, evidently the two share enough leading features so that they probably belong to the same family; and both are most conveniently excluded from the Hydrobiidae.

#### Hydrobiinae

Verge with only one duct, the vas deferens (contrast Amnicolinae and Fontigentinae), and with or without accessory processes on the left side that (when present) are glandular and widest at the base (contrast Littoridininae). Eyes in low, discrete swellings on the outer bases of the tentacles (contrast Lithoglyphinae). Pigmentation consists only of melanin; no yellow granules are present in the head-foot (contrast Lithoglyphinae). Operculum corneous, paucispiral (contrast Cochliopinae, Lyogyridae, Nymphophilinae). Shell globose to turritiform, anomphalous to phaneromphalous (contrast Cochliopinae); aperture thickened or thin, but not flared (contrast *Pterides*-group; reproduction ovoviviparous, or eggs laid singly<sup>7</sup>, in smooth capsules with no dorsal laminate crest (contrast Amnicolinae); progression smooth and not step-wise (contrast Pomatiopsinae).

In the present state of knowledge the Hydrobiinae consist of (a) genera similar to *Hydrobia*, and (b) those left over when obviously distinct groups have been separated. The diagnosis is therefore unwieldy, and the group will surely be refined as knowledge increases.

The descriptions and illustrations by MUUS (1963) permit for the first time a comparison of typical *Hydrobia*

<sup>7</sup> An exception is the brackish-water genus *Hydrobia*; see FRETTER & GRAHAM (1962) and references therein.



with American Hydrobiidae on the basis of several characters. The most similar genus in America seems to be *Marstonia*: it has an elongate, turritiform shell with an acute apex, and a simple verge in which the left lateral accessory process is smaller than in most American fresh-water Hydrobiidae. Other genera close to *Hydrobia* are *Probythinella* (closer to *Hydrobia* than is *Marstonia* in the verge, but with a distinctive truncate shell) and *Fontelicella* (much like *Hydrobia* in shell, but with an elaborate, bulky accessory process). Other genera are progressively less similar to *Hydrobia*, and most of them are so poorly known that they cannot be grouped plausibly. The following list of genera of Hydrobiinae should be taken with this reservation.

**Referred genera:** On account of the number of groups involved, and the dubious reference of some, virtually no lists of species or summaries of distribution have been compiled. Literature is accessible through the works by F. C. BAKER (1928), E. G. BERRY (1943), and WENZ (1938-1944); more recent papers describing new genera are cited in the bibliography of this paper.

*Aroapyrgus* H. B. BAKER, 1931 (*Aroa* H. B. BAKER, 1930, non WALKER, 1855).

*Birgella* F. C. BAKER, 1926

*Cincinnatia* PILSBRY, 1891

*Clappia* WALKER, 1909

*Fontelicella* GREGG & TAYLOR, 1965

*Gillia* STIMPSON, 1865

*Hoyia* F. C. BAKER, 1926

*Hydrobia* HARTMANN, 1821

*Marstonia* F. C. BAKER, 1926

*Notogillia* PILSBRY, 1953

*Probythinella* THIELE, 1928

*Pyrgulopsis* CALL & PILSBRY, 1886

*Somatogyrys* GILL, 1863

*Walkerilla* THIELE, 1928

In reviewing tropical American genera of subfamilies other than Hydrobiinae I had to consult practically all the literature on *Aroapyrgus*, and reviewed that genus along with others. The shell is not distinctive, and probably other species now *incertae sedis* will be included.

*Aroapyrgus* BAKER, 1931

*Aroa* BAKER, 1930. Occ. Pap. Mus. Zool. Univ. Mich. 210: 35. Type (O.D.): *Potamopyrgus ernesti vivens* BAKER. Not of WALKER, 1855.

*Aroapyrgus* BAKER, 1931. Nautilus 44: 143. New name for *Aroa* BAKER.

The following species have been described:

*Aroapyrgus alleei* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 14, pl. 2, fig. 4; pl. 3, fig. 3. Allee Stream, Barro Colorado Island, Gatun Lake, Panama Canal Zone.

*Aroapyrgus chagresensis* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 14, pl. 2, fig. 3; pl. 3, fig. 4. Río Chagres, near Gatuncilla, Panamá. Also recorded by Morrison from the Río Chagres, near Madronal, Panamá.

*Aroapyrgus ernesti* (VON MARTENS, 1873) (*Hydrobia*). Festschr. Gesellsch. Naturforsch. Freunde Berlin: 209, pl. 2, fig. 12. Subfossil, Lago de Valencia, Venezuela.

*Aroapyrgus globulus* (BAKER, 1930) (*Potamopyrgus*). Occ. Pap. Mus. Zool. Univ. Mich. 210: 36, pl. 28, fig. 3. "Venezuela," no precise locality.

*Aroapyrgus joseana* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 15, pl. 2, fig. 5; pl. 3, fig. 8. Northern tributary of Río Mata Puerco estuary, San José Island, Archipiélago de las Perlas, Panamá. Also recorded by Morrison from 3 other localities on the same island.

*Aroapyrgus latus* (HAAS, 1949) (*Potamopyrgus*). An. Inst. Biol. Mex. 20: 312, text-fig. 5. Río Tapajóz, Santarém, bay Mapire, Pará, Brasil. Also recorded by HAAS (1949, 1950, 1952) from several other localities in the lower Amazon valley, Brasil.

*Aroapyrgus panamensis* (TRYON, 1863) (*Amnicola*). Proc. Acad. Nat. Sci. Philadelphia 15: 146, pl. 1, fig. 6. Panamá (no specific locality). So assigned by Morrison (1946).

*Aroapyrgus putealis* (BAKER, 1930) (*Potamopyrgus*). Occ. Pap. Mus. Zool. Univ. Mich. 210: 35, pl. 28, figs. 2, 5. Pond a few kilometers above the town of Estación Táchira, near the left bank of Río Lobaterita, state of Táchira, Venezuela.

*Aroapyrgus ernesti vivens* (BAKER, 1930) (*Potamopyrgus*). Occ. Pap. Mus. Zool. Univ. Mich. 210: 33, pl. 28, figs. 1, 4, 6, 7. Quebrada Vaca, tributary to Quebrada Carabobo, southeast by south from Boquerón, state of Yaracuy, Venezuela. Recorded by Baker from several localities in central and western Venezuela.

BAKER (1930) noted that females reach a larger size than males. Numerous embryonic young were observed in *Aroapyrgus ernesti vivens* and *A. putealis*. The shell is relatively shorter and wider than that of *Pyrgophorus*, and the central tooth of the radula bears 2 instead of 3 basal denticles. The verge is simple, with no accessory glands, arises from inside a circular fold around its base, and originates markedly to the right of the midline rather than in the midline as in *Pyrgophorus*. The distal half of the verge is pigmented, and narrower than the unpigmented proximal half.

This group was established as a subgenus of *Potamopyrgus* (*Pyrgophorus* as used herein) by BAKER, and subsequently raised to generic rank by MORRISON (1946). According to the criteria for subdivision of the Hydrobiidae used herein, *Aroapyrgus* is not even in the same subfamily as *Pyrgophorus*. The origin of the verge from



within a circular fold is unique in Hydrobiidae, and one may wonder whether the genus is properly included in the Hydrobiinae.

#### Hydrobiinae? *incertae sedis*

(Text figure 4)

Two specimens, each from a different locality, represent a smooth-shelled small species that cannot be assigned to genus on shell characters.

*Localities and material examined:* Unnamed laguna west of Río Churince; D. W. Taylor, 14-IV-1965 (UMMZ 220157) (figured specimen). Río Mesquites, 9 km SW Cuatro Ciénegas; D. W. Taylor, 13-IV-1965 (UMMZ 220184).

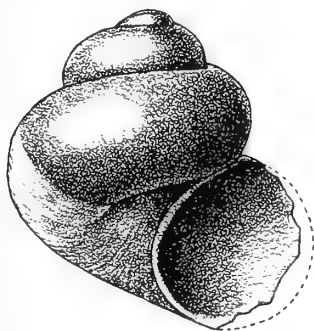


Figure 4

Hydrobiinae, *incertae sedis*. Figured specimen, UMMZ 220157. Length 1.1 mm; width 1.0 mm; 3 whorls.

#### Amnicolinae TRYON, 1866

Hydrobiidae with a verge including 2 ducts: the vas deferens, and an accessory duct in a lateral appendage on the left. Eggs in single capsules with a dorsal ridge. Operculum corneous, paucispiral. Shell with blunt apex.

Referred genera: *Amnicola* HALDEMAN, 1840 (widely distributed in North America; 3 species).

*Marstoniopsis* ALTENA, 1936 (northwestern Europe; 1 species).

A group name based on *Amnicola* goes back to TRYON (1862) or GILL (1863); but the scope and relatively narrow definition of this group date only to TRYON (1866).

*Amnicola* is known mainly by the studies of E. G. BERRY (1943). According to this work only *Amnicola* has egg capsules with a dorsal laminate ridge. The accessory duct has not been described in detail, but as illustrated (E. G. BERRY, 1943, text-fig. 1, 2) it originates in or close to the base of the verge. Only 3 species are surely referable to *Amnicola*:

*Amnicola limosa* (SAY, 1817), found "from the Atlantic coast as far west as Utah, and from Labrador to Florida" (E. G. BERRY, 1943:23).

*Amnicola walkeri* PILSBRY, 1898, found in the Great Lakes region. This is probably a junior synonym of *Paludina lustrica* SAY (1821), as discussed previously (TAYLOR, 1960).

*Amnicola greggi* (PILSBRY, 1935b). This species was described originally as *Hydrobia*, a generic name used for a long time for small Hydrobiidae with no marked shell characters. Observation of living material from the type locality in western Wyoming, and from western Montana and southeastern Idaho, U.S.A., shows that it has the laminate egg capsules, verge with 2 ducts, and other external features of *A. walkeri* of Michigan.

#### *Marstoniopsis* ALTENA, 1936

Basteria 1:68. Type (O.D.): *Hydrobia steinii* (VON MARTENS).

KRULL (1935) and ALTENA (1936) have contributed most of what is known about *Marstoniopsis*. FRETTER & GRAHAM (1962: 590-591) evidently referred to *M. steinii* by the name *Bythinella scholtzi*, a synonym according to ALTENA (1936). The species was introduced from continental Europe to England, not from America as stated by FRETTER & GRAHAM. The similarities to the American genus *Marstonia* that ALTENA (1936) pointed out are due to errors by F. C. BAKER (1928). In North America *Amnicola* is markedly distinct in its egg capsules and verge, and it is to this genus that *Marstoniopsis* is clearly similar.

Whether the European genus *Bythinella* should be grouped with *Amnicola* and *Marstoniopsis* is uncertain in the present state of knowledge. As described and illustrated by BREGENZER (1916) and KRULL (1935), the egg capsules are smooth, without a dorsal ridge; the distal end of the accessory process is swollen; and the accessory duct has a far longer and more swollen base than in *Amnicola*. If *Bythinella* is to be added to the Amnicolinae then the diagnosis given above must be modified.

#### Cochliopinae TAYLOR, new subfamily

Shell trochoid to planispiral, narrowly to broadly umbilicate. Operculum with subcentral nucleus and 3-5 whorls. Rostrum and tentacles with or without 1-2 transverse melanin-pigmented bands. Verge with only 1 duct (vas deferens), with or without 1-2 small accessory processes on the left side. Reproduction ovoviviparous in the 1 genus where known.

Within the Cochliopinae 3 subordinate groups can be recognized that are formalized as tribes (see distribution map, Text figure 5):

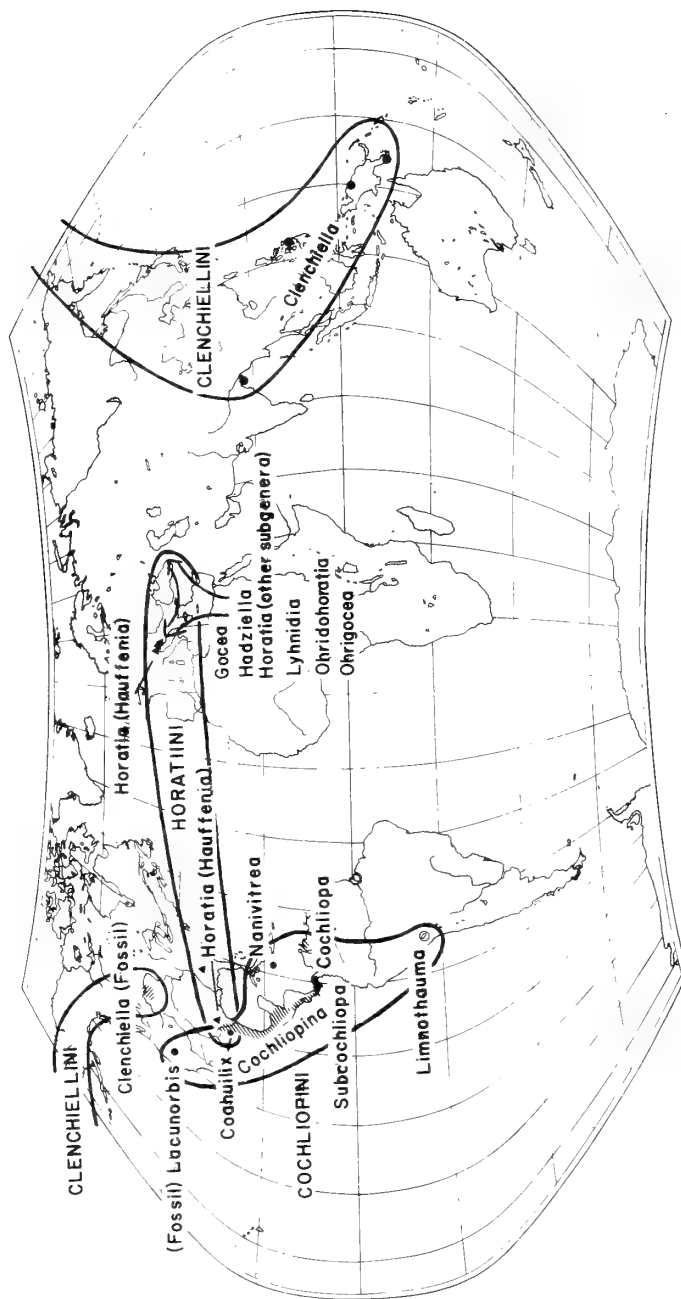


Figure 5

Distribution of subfamily Cochliopinae of family Hydrobiidae.

**Cochliopini**, new rank: shell large for the subfamily, minute to medium-sized for the family, generally trochoid with medium-sized to broad umbilicus. Carinae and spiral cords on the shell or color bands in the periostracum may be present. Tropical and warm-temperate America. Referred genera:

*Cochliopa* STIMPSON, 1865, Panamá (3 species)

*Cochliopina* MORRISON, 1946, southwestern Texas to Panamá and northwestern Venezuela (20 species)

— *Lacunorbis* YEN, 1950, Pliocene, Nevada, U.S.A. (1 species)

*Limnothauma* HAAS, 1955a, Lake Titicaca, Perú (1 species)

— *Nanivitrea* THIELE, 1927, Cuba and Jamaica (4 species)

— *Subcochliopa* MORRISON, 1946, Costa Rica and Panamá (3 species)

**Horatiini**, new tribe: shell minute, planispiral to trochoid, lacking spiral sculpture or color bands; mostly subterranean, found in karst regions. Southeastern North America and southeastern Europe as far east as the Caucasus.

Referred genera:

— *Coahuilix* TAYLOR, gen. nov., Coahuila, México (1 species)

— *Gocea* HADŽIŠČE, 1956a, Lake Ohrid, Yugoslavia-Albania (1 species)

— *Hadziella* KUŠČER, 1932, Yugoslavia (2 species).

*Horatia* BOURGUIGNAT, 1887, with 3 subgenera besides the typical subgenus:

(*Horatia*) s.s. Yugoslavia and Albania (several species)

(*Daudebardiella*) O. BOETTGER, 1905, Cilicia, Turkey (a few species)

(*Hauftenia*) POLLONERA, 1898, southeastern Europe (8 species, from northeastern Italy and Austria to Dalmatia, Yugoslavia) and southern U.S.A. (2 species in Texas and Alabama)

(*Neohoratia*) SCHÜTT, 1961, southeastern Europe to Caucasus Mts., USSR (about 10 species)

*Lyhndia* HADŽIŠČE, 1956b, Lake Ohrid, Yugoslavia-Albania (4 species)

*Ohridohoratia* HADŽIŠČE, 1956b, Lake Ohrid, Yugoslavia-Albania

(*Ohridohoratia*) s.s. (2 species)

(*Ohridohauftenia*) HADŽIŠČE, 1956b (1 species)

*Ohriogocea* HADŽIŠČE, 1956b, Lake Ohrid, Yugoslavia-Albania

(*Ohriogocea*) s.s. (2 species)

(*Karevia*) HADŽIŠČE, 1956b (3 species)

**Clenchiellini**, new tribe: shell small, planorboid. Two carinae may be present; spiral cords or color bands are unknown. Northwestern North America (early Tertiary only) and southeastern Asia. One genus:

*Clenchiella* ABBOTT, 1948 (6 species).

Few morphological data are available for members of this group, so they are tied together by only a few characters. In practically all Hydrobiidae the shell is turritiform to globose and the operculum is paucispiral with its nucleus near the anterior-columellar side. Thus the features of shell and operculum in Cochliopinae are especially distinctive. The black tentacular bands of *Clenchiella* are found in species of *Cochliopa*, *Cochliopina*, and *Subcochliopa*, but the significance of this character is somewhat lessened by similar pigmentation in *Hydrobia*. No such bands occur in any Nearctic Hydrobiidae I have examined.

A particularly distinctive feature of *Clenchiella* is the series of 6-7 low swellings on the proximal posterior border of the left tentacle. This is unique in Hydrobiidae so far as known, but it is like the structure of the marine Caecidae and Vitrinellidae as described by MOORE (1962). The rarity of this tentacular structure alone might suggest the homology of these swellings on the left tentacle. Other characters are common to Cochliopinae and Vitrinellidae, however: a multispiral operculum with subcentral nucleus, and a low trochoid shell with broad umbilicus and strong spiral sculpture. These features are not associated in all species of these groups, but they are common and characteristic. Taken together these features suggest phylogenetic relationship. I suggest that the Vitrinellidae are derived from Cochliopinae of the Hydrobiidae. Such an interpretation, based on morphological grounds, is supported by the fact that *Clenchiella* is one of the few known Hydrobiidae living in brackish water.

#### Tribe Cochliopini, new rank

This group is the subfamily Cochliopinae of TRYON (1866) for all practical purposes. Species of only 2 genera (*Cochliopa* and *Cochliopina*) were known at that time, but TRYON's differential features included the same characters of shell form used here.

*Cochliopa* STIMPSON, 1865

Amer. Journ. Conch. 1: 52. Type (O.D.): *Cochliopa rowelli* (TRYON).

The radula of *Cochliopa rowelli* has been described by STIMPSON (1865 a, b) and MORRISON (1946). Pattern of verge and pigmentation of the 3 named species have been illustrated by MORRISON (1946).

The species are all from the Pacific drainage, in the Isthmus of Panamá and Pearl Islands, Panamá.

*Cochliopa diazensis* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 27, pl. 2, fig. 15; pl. 3, fig. 18. Río Juan Díaz just below Las Sabanas Road bridge, east of Panamá City, Panamá.

*Cochliopa joseana* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 28, pl. 2, fig. 18; pl. 3, fig. 19. Río Mata Puerco, San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopa rowellii* (TRYON), 1863b (*Amnicola*). *Proc. Acad. Nat. Sci. Philadelphia* 15: 147, pl. 1, figs. 8-9. The type locality of the species was first published as Clear Lake, Lake County, California, but Rowell, the collector, later asserted it was at Baulinas Bay, Marin County, California (ROWELL, 1906). PILSBRY (1905, 1920), PILSBRY & FERRISS (1906), and MORRISON (1939b) have concluded the type locality is in Panamá; and MORRISON (1946) located it more precisely as the Río Matasnillo immediately east of Panamá City, Panamá.

#### *Cochliopina* MORRISON, 1946

*Smithson. Misc. Coll.* 106 (6): 18. Type (O.D.): *Cochliopina riograndensis* (PILSBRY & FERRISS), 1906.

This genus is one of the few known groups of Hydrobiidae with color pattern in the shell. The feature is common in the genus, although not present in all species, and unknown in other genera of Cochliopinae. The pattern is confined to the periostracum and consists of fine, spiral, continuous brown bands of variable width, usually correlated with spiral ridges of the shell, and sometimes fused to form broad bands.

Ovoviviparity is known in 2 species besides *Cochliopina milleri* TAYLOR, spec. nov. GOODRICH & VAN DER SCHALIE (1937) found 3 young in a specimen of *C. francesae*, and LEONARD & HO (1960b) found 30-50 young per adult *C. riograndensis*.

Previously published morphological data are scanty. The pattern of the verge and pigmentation of the head have been illustrated by MORRISON (1946) in 7 Panamanian species. The operculum was illustrated by MORRISON (1946) for *Cochliopina zeteki*, and by LEONARD & HO (1960b) for *C. riograndensis*. The radula of *C. riograndensis* was illustrated by LEONARD & HO (1960b) for *C. riograndensis*, and that of *C. minor* was formulated by MORRISON (1946).

Twenty nominate forms of *Cochliopina* occur from southwestern Texas, in the Río Grande drainage, southward to Panamá and northwestern Venezuela. "All the northern species, ranging from Texas through México to eastern Guatemala as far as Lake Izabal and the Río Dulce, are found only in river systems draining into the Gulf of México and the Caribbean. In contrast, all the

species known from the southeast corner of Guatemala, southward through Nicaragua, Costa Rica, Panamá, and the Pearl Islands in the Gulf of Panamá, occur only in streams of the Pacific drainage" (MORRISON, 1946:18).

The described forms were mostly listed by MORRISON (1946), but for the sake of a complete summary of the American species of the subfamily they are listed again here.

*Cochliopina australis* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 23, pl. 2, fig. 13; pl. 3, fig. 14. Musselshell Creek, San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopina compacta* (PILSBRY, 1910) (*Cochliopa*). *Nautilus* 23: 99, pl. 9, figs. 4-5. Río Choy at the cave, south of Las Palmas, San Luis Potosí, México. So assigned by MORRISON (1946).

*Cochliopina dulcensis* (MARSHALL, 1920) (*Cochliopa*). *Proc. U. S. Nat. Mus.* 58: 302, pl. 17, figs. 1-3. Río Dulce, Guatemala. So assigned by MORRISON (1946).

*Cochliopina extremis* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 22, pl. 2, fig. 11; pl. 3, fig. 13. Southern tip of San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopina francesae* (GOODRICH & VAN DER SCHALIE, 1937) (*Cochliopa*). *Misc. Publ. Mus. Zool. Univ. Mich.* 34: 38, pl. 1, fig. 3. Drainage basin of Río de la Pasión, Dept. Petén and Alta Vera Paz, Guatemala. So assigned by MORRISON (1946).

*Cochliopina fraternula* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 21, pl. 2, fig. 9; pl. 3, fig. 11. Río Mata Puerco, San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopina guatemalensis* (MORELET, 1851) (*Valvata*). *Test. Noviss.* 2: 22. Río Michatoya, near Istapa, Guatemala. So assigned by MORRISON (1946).

*Cochliopina hinkleyi* (PILSBRY, 1920) (*Cochliopa*). *Proc. Acad. Nat. Sci. Philadelphia* 72: 198, text-fig. 4. Lake Izabal near Jocolo, Guatemala. So assigned by MORRISON (1946).

*Cochliopina infundibulum* (MARTENS, 1899) (*Cochliopa*). *Biol. Centr.-Amer., Moll.*: 429, pl. 23, fig. 3. Guatemala (no precise locality). So assigned by MORRISON (1946), who specified the locality Petén, Guatemala.

*Cochliopina izabal* (PILSBRY, 1920) (*Cochliopa*). *Proc. Acad. Nat. Sci. Philadelphia* 72: 200, text-fig. 6. Lake Izabal near Jocolo, Guatemala. So assigned by MORRISON (1946).

*Cochliopina juradoi* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 20, pl. 2, fig. 8; pl. 3, fig. 10. Stream leading to northwest mangrove swamp, San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopina kugleri* (FORCART, 1948) (*Valvata*). *Verhandl. Naturforsch. Gesellsch. Basel* 59: 50, pl. 1, figs.

6a-d. Distr. Acosta, State of Falcón, Venezuela. I have not seen specimens of this form, but reference to the genus *Cochliopina* seems much more likely than to the similar-looking but remote genus *Valvata*.

*Cochliopina minor* (PILSBRY, 1920) (*Cochliopa*). Proc. Acad. Nat. Sci. Philadelphia 72: 199, text-fig. 5. Polvon, Nicaragua. So assigned by MORRISON (1946).

*Cochliopina navalis* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 22, pl. 2, fig. 12; pl. 3, fig. 12. Stream tributary to bay on southwestern San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopina izabal* mutation *perstriata* (PILSBRY, 1920) (*Cochliopa*). Proc. Acad. Nat. Sci. Philadelphia 72: 201, text-fig. 7. Lake Izabal near Jocolo, Guatemala. So assigned by Morrison (1946).

*Cochliopina picta* (PILSBRY, 1910) (*Cochliopa*). Nautilus 23: 100, pl. 9, figs. 1-2. Río Choy near the ford on the road to Tampamolón, and Río Ganina near Rascón; both San Luis Potosí, México. So assigned by MORRISON (1946).

*Cochliopina riograndensis* (PILSBRY & FERRISS), 1906 (*Cochliopa*). Proc. Acad. Nat. Sci. Philadelphia 58: 171, pl. 9, figs. 10-13. Drift of Río San Filipe near Río Grande, Val Verde County, Texas. Found from Río Grande southward to Río Pánuco, San Luis Potosí, México (PILSBRY, 1920).

*Cochliopina tryoniana* (PILSBRY, 1890) (*Cochliopa*). Nautilus 4: 52. Polvon, Nicaragua. So assigned by MORRISON (1946).

*Cochliopina wetmorei* MORRISON, 1946. Smithson Misc. Coll. 106 (6): 24, pl. 2, fig. 16; pl. 3, fig. 15. Río Marina, San José Island, Archipiélago de las Perlas, Panamá.

*Cochliopina zeteki* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 19, pl. 2, fig. 7; pl. 3, figs. 5, 9. Río Juan Díaz, just below Las Sabanas Road bridge, east of Panamá City, Panamá.

*Cochliopina riograndensis* (PILSBRY & FERRISS, 1906)  
On the way to the valley of Cuatro Ciénegas, Coahuila, I found *Cochliopina riograndensis* living at 2 localities, 1 in Texas and the other in Coahuila. To my observations on habitat I have added a list of the localities represented in University of Michigan collections.

LEONARD & HO (1960b) have published the only record of occurrence of the species alive. They found it in Independence Creek, Terrell County, Texas, "... living in relatively sluggish water about six inches deep in the clear, cool, fast-flowing stream. *C. riograndensis* was here restricted to the edge of the stream, and was fairly abundant under cobbles of limestone, logs, and in aquatic vegetation."

In Río Salado de los Nadadores at El Cariño, Coahuila (Plate 12, Fig. 10), *Cochliopina* occurred in both a spring beside the river and in protected situations along the edge of the stream. It was sparse in the mud of the spring-pool,

but common among watercress in the fine mud along the stream border.

A similar habitat beside the Devils River at Bakers Crossing, Val Verde County, Texas, also yielded numerous *Cochliopina*. They were most abundant in the soft mud bottom of a seepage-fed pool, where there was an abundant growth of *Chara* and *Myriophyllum*. *Cochliopina* was also in mud at the edge of the main stream, though scarce, and specimens found here were smaller and with less conspicuous color-banding than in the seepage.

The University of Michigan Museum of Zoology has the following lots of *Cochliopina riograndensis* (PILSBRY & FERRISS).

TEXAS, Val Verde County. Pecos River, 7 miles SE Shumla; Leslie Hubricht, 25-V-1938 (UMMZ 197722). Drift of Pecos River at crossing of U. S. highway 90; Leslie Hubricht, 14-V-1955 (UMMZ 197719). Devils River, Bakers Crossing, 22 miles N Comstock; Leslie Hubricht, 24-V-1938 (UMMZ 197720); D. W. Taylor, 11-IV-1965 (UMMZ 220228). Devils River at crossing of U. S. highway 90; Leslie Hubricht, 12-VI-1955 (UMMZ 195512). Devils River N of Del Rio; Leslie Hubricht, 27-II-1955 (UMMZ 197721).

Kinney County. No specific locality; ex Andrews coll. (UMMZ 91726, 117257); ex J. R. Tomlin coll. (UMMZ 117252).

TAMAULIPAS. Storms ranch, Pano Ayuctla, 5 miles NE Gómez Farías; Rez Darnell, 29-V-1951 (UMMZ 191821), 30-V-1951 (UMMZ 191823). Arroyo Encino, 5 miles NE Gómez Farías; Rez Darnell, 26-V-1951 (UMMZ 191824). Arroyo Encino, above Encino, E of Gómez Farías; Rez Darnell, 23-IV-1951 (UMMZ 191822). Río Sabinas at Pan American highway E of Gómez Farías; Rez Darnell, 25-V-1951 (UMMZ 191826). Rancho Pico de Oro, on Río Sabinas E of Gómez Farías; Rez Darnell, 30-IV-1951 (UMMZ 191825).

COAHUILA. Río Salado de los Nadadores, El Cariño de la Montaña, 20 km E of Cuatro Ciénegas; D. W. Taylor, 12-IV-1965 (UMMZ 220145).

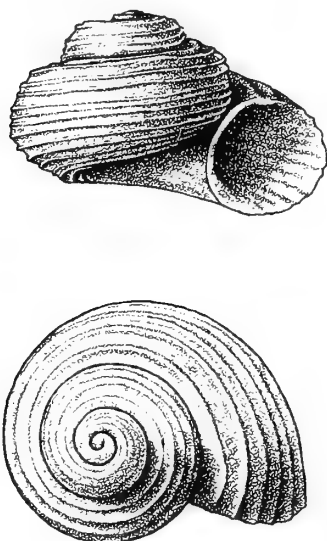
SAN LUIS POTOSÍ. Río Valles, Valles; A. A. Hinkley (UMMZ 28992, 69439, 117251, 117253). Río Ganina, Rascón; A. A. Hinkley (UMMZ 117254).

*Cochliopina milleri* Taylor, spec. nov.

(Text figures 6, 7; Plate 13, Figures 12, 13)

**Diagnosis.** Shell about 3 mm in diameter, broadly conical with an abruptly truncate apex, nearly circular whorls, and a broad umbilicus about  $\frac{1}{3}$  of the shell diameter. Sculpture consists of about 12-15 spiral cords, covered by dark brown periostracal color bands, that are separated

by approximately equal spaces 4-6 times as wide as the cords.



Figures 6 and 7

*Cochliopina milleri* TAYLOR, spec. nov. Type, UMMZ 220182.  
Length 2.8 mm; width 3.3 mm;  $3\frac{1}{2}$  whorls.

**Type.** UMMZ 220182. Coahuila, México: Río Mesquites at the main road 9 km southwest of Cuatro Ciénegas. D. W. Taylor, 13-IV-1965. Fifty-eight other specimens from the same collection are UMMZ 220183. The species is known only from the type locality (Text figure 2, locality 11).

**Comparison and discussion.** The most closely similar species are from Guatemala; they are *C. dulcensis* (MARSHALL), from Río Dulce and Lago Izabal; *C. francesae* (GOODRICH & VAN DER SCHALIE), from the drainage of Río de la Pasión; and *C. infundibulum* (MARTENS), of Dept. Petén. These all share with *C. milleri* the distinctive features of a broadly conical shape, whorls roughly circular in cross-section, wide umbilicus, and sculpture of strong spiral cords.

*Cochliopina infundibulum* differs by its more conical shape, with a more nearly acute apex. A cord on the shoulder of the shell is often conspicuous, but the whorls are not tabulate as in *C. milleri*, and the umbilicus is often but not consistently narrower. No shells with periostracum are available.

*Cochliopina dulcensis* has fewer and stronger spiral cords than *C. milleri*, and a wider umbilicus and more depressed shape. It is similar to *C. milleri* in its truncate apex, and strong cord on the shoulder of a tabulate whorl. The periostracum on the spiral cords may be more deeply colored than in between, or with no darker color band.

Abundant material of *Cochliopina francesae* is available for comparison, and perhaps for this reason it seems more variable than the other species. It is smaller, usually with an acute rather than truncate apex, and a narrower umbilicus than in *C. milleri*. The strength and spacing of the cords is often as in *C. milleri*, but the shoulder of the whorl may be less pronounced. Color banding is weak or absent. The range of variation is so great that some specimens of *C. francesae* may be indistinguishable from some *C. milleri*. **Habitat.** *Cochliopina milleri* was found only in the Río Mesquites (Plate 11, Figure 8), where it occurred in soft mud in backwaters and protected places along the edge of the stream, associated with *Mexipyrus lugoi* TAYLOR, spec. nov. Unlike the latter, it did not occur also in the main current.

**Morphology and biology.** All 49 living specimens of *Cochliopina milleri* were females with embryos in the lower part of the pallial oviduct in various stages of development. Evidently males are at least rare in this population, but the extent of collecting is inadequate to indicate parthenogenesis in the species.

**Etymology.** The species is named in honor of R. R. Miller, University of Michigan Museum of Zoology. The name is doubly appropriate, because of his study of fishes in the Cuatro Ciénegas area; and because one of the most similar species to this new form, *Cochliopina francesae* (GOODRICH & VAN DER SCHALIE), is named for his wife, Frances Hubbs Miller.

*Lacunorbis* YEN, 1950

Amer. Jour. Sci. 248:187. Type (O. D.): *Lacunorbis nevadensis* YEN.

### Explanation of Plate 13

Snails from the Valley of Cuatro Ciénegas, Coahuila.

Photographed by John Tottenham.

Figures 11, 14, 16: *Paludiscala caramba* TAYLOR, gen. et spec. nov.

11. Type, UMMZ 220164. Length 2.5 mm, width 1.2 mm,  $7\frac{1}{2}$  whorls.

14. Figured specimen, UMMZ 220165. Length 2.6 mm, width 1.4 mm,  $6\frac{3}{4}$  whorls.

16. Figured specimen, UMMZ 220165. Length 2.3 mm, width 0.9 mm,  $7\frac{1}{2}$  whorls.

Figures 12, 13: *Cochliopina milleri* TAYLOR, spec. nov.

Type, UMMZ 220182. Length 2.8 mm, width 3.3 mm,  $3\frac{1}{2}$  whorls.

Figures 15, 17: *Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

Type, UMMZ 220188. Length 7.0 mm, width 6.0 mm,  $5\frac{3}{4}$  whorls.



Figure 11

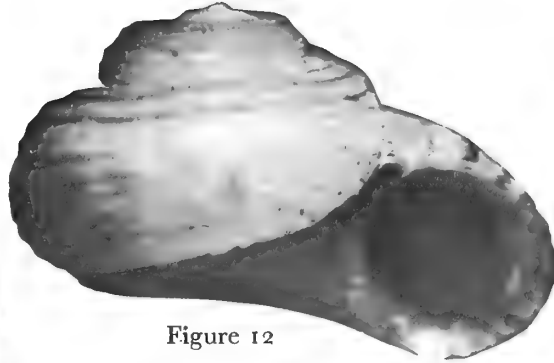


Figure 12

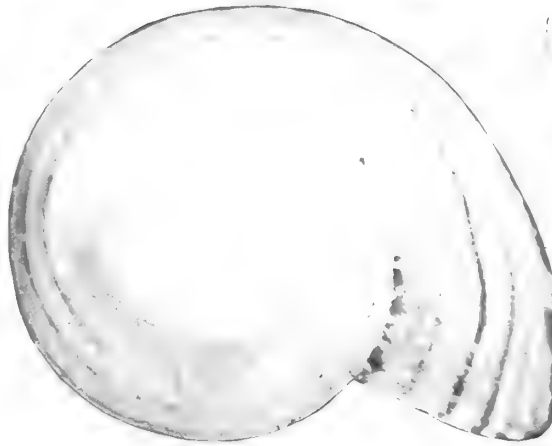


Figure 13



Figure 14



Figure 15



Figure 16

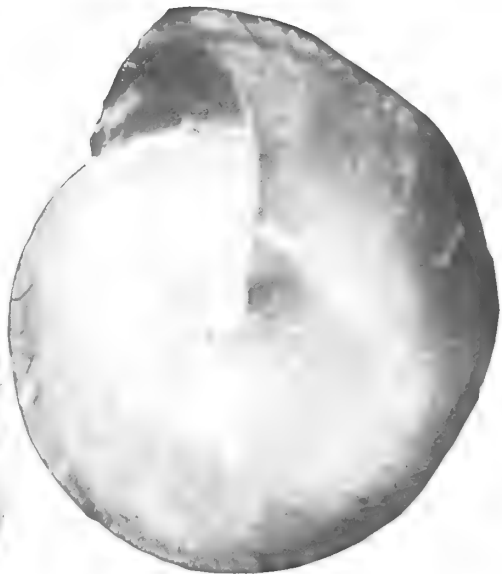


Figure 17





*Lacunorbis nevadensis* YEN, 1950. Amer. Jour. Sci. 248: 187, pl. 1, figs. 7-7b. Pliocene, Truckee Formation, Hot Springs Mountains, Churchill County, Nevada, U.S.A.

*Limnothauma* HAAS, 1955

Trans. Linn. Soc. London, ser. 3, 1: 302. Type (O. D.): *Limnothauma crawfordi* HAAS.

The anatomy is unknown. The operculum is paucispiral with about  $2\frac{1}{2}$  whorls; its apex is subcentral, closer to the center than in most Hydrobiidae but not as close as in some Cochliopinae. A unique feature of the operculum is that it projects over the edges of the aperture and cannot be drawn within. The trochoid shape, broad umbilicus, and basal carination are reminiscent of *Lacunorbis* rather than geographically nearer Cochliopinae.

*Limnothauma crawfordi* HAAS, 1955. Trans. Linn. Soc. London, ser. 3, 1: 302, text-fig. 28. Isla Titicaca, Lake Titicaca, Perú.

*Nanivitrea* THIELE, 1927

Zool. Jahrb., Abt. Syst., Ökol. u. Geogr., 53: 126. Type (O.D.): *Nanivitrea helicoides* (GUNDLACH).

The broadly conical shell form of *Nanivitrea* is like that of *Cochliopina*, as noted by JAUME & ABBOTT (1948). This resemblance, and the operculum of *N. alcaldei* ("paucispiral but approaching multispiral in appearance, and with approximately 3 or 4 whorls") are features favoring assignment to the Cochliopinae. JAUME & ABBOTT (1948) figured the radula of *N. alcaldei*; no further morphological data on the genus are available.

*Nanivitrea alcaldei* JAUME & ABBOTT, 1948. Rev. Soc. Malac. "Carlos de la Torre" 6:5, text-fig. 1a-c, 4. Finca de Pollán, Naranjo, Trinidad, Prov. Las Villas, Cuba.

*Nanivitrea helicoides* (GUNDLACH, 1865) (*Paludinella*). Poey, Repertorio físico y natural de la Isla de Cuba 1:70. Cardenas and Matanzas, Prov. Matanzas, Cuba.

*Nanivitrea inconspicua* (ADAMS, 1851) (*Valvata*). Contrib. Conch.: 131. Jamaica. So assigned by JAUME & ABBOTT (1948).

*Nanivitrea pygmaea* (ADAMS, 1849) (*Valvata*). Contrib. Conch.: 42. Jamaica. So assigned by JAUME & ABBOTT (1948).

*Subcochliopa* MORRISON, 1946

Smithson. Misc. Coll. 106 (6): 25. Type (O.D.): *Subcochliopa trochus* MORRISON.

*Subcochliopa colabrensis* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 26, pl. 2, fig. 14, pl. 3, fig. 16. Río Colabre, Río Bayano drainage, Panamá.

*Subcochliopa trochulus* (VON MARTENS, 1899) (*Cochliopa*). Biol. Cent.-Amer., Moll.: 429, pl. 23, fig. 2. Río Gran-

de de Terraba at El Pozo, and in marshes of Sierpe, southwestern Costa Rica. So assigned by MORRISON (1946).

*Subcochliopa trochus* MORRISON, 1946. Smithson. Misc. Coll. 106 (6): 25, pl. 2, fig. 17, pl. 3, fig. 20. Río Tribique, Sona, Veraguas Province, Panamá.

Spurious Cochliopini

BURCH (1946) listed 3 species of *Cochliopa* from notes compiled by the late A. M. Strong. Of these species *Cochliopa rowelli* (TRYON) is the type species of *Cochliopa*, and *Cochliopa trochulus* MARTENS is now classified in *Subcochliopa*. The species listed as "*Cochliopa currugata* STEARNS, 1890," from Nicaragua seems to be an error based on the marine snail *Cyclothyca corrugata* (STEARNS), of the family Capulidae.

Cochliopini incertae sedis

"*Planorbis*" *bourguyi* ROXO, 1924. Bol. Brasil Serv. Geol. Mineral. 11:50, fig. E. Pliocene?, Tres Unidos, Prov. Loreto, Perú. Perhaps Cochliopinae.

"*Cochliopa*" *chihuahua* (PILSBRY, 1928) (*Fluminicola*). Proc. Acad. Nat. Sci. Philadelphia 80:116, text-fig. 3. Ojo Caliente, Chihuahua, México. So referred by PILSBRY (1935b).

"*Planorbis*" *pebasana* CONRAD, 1874. Proc. Acad. Nat. Sci. Philadelphia 26:30. Pliocene?, Pebas, or Pichana, or Old Pebas, Prov. Loreto, Perú. Probably Cochliopinae rather than Planorbidae, particularly if the specimens described and illustrated by DE GREVE (1938) represent CONRAD's species.

"*Cochliopa*" *texana* PILSBRY, 1935. Nautilus 48:91, text-figs. 5a-b. Phantom Lake near Toyahvale, Reeves County, Texas. The species is not referable to *Cochliopa* in the strict sense according to MORRISON (1946). The relatively numerous whorls of the operculum and subcentral nucleus (specimens examined in UMMZ collection) show it is one of the Cochliopinae.

"*Planorbis*" sp. DE GREVE, 1938. Abh. Schweiz. Palaeont. Gesellsch. 61:(3):107, pl. 4, figs. 29-30. Pliocene?, Iquitos, Prov. Loreto, Perú. Probably Cochliopinae rather than Planorbidae.

Tribe Horatiini, new tribe

Little biological information about this group is available. Most of the species are known only by shells found in stream-drift from springs or in caves, except for those in and around Lake Ohrid, Yugoslavia-Albania. The planispiral to trochoid shape, and multispiral operculum are both unusual characters in the family that are shared with the Cochliopinae, but the shells are minute, thinner, and lack color pattern. Morphological information on European Horatiini is mainly due to papers by RADOMAN

(1953, 1955a, b). Little is known of any American Horatiini. Comparison is further made difficult because much of Radoman's data concern the nervous system and stomach, completely unknown in American Cochliopinae. Hence the appropriateness of grouping the Horatiini in the Cochliopinae can scarcely be weighed in spite of a substantial body of information.

In the United States *Horatia* is known by 2 nominal forms, *Horatia (Hauffenia) micra* (PILSBRY & FERRISS, 1906) and *H. micra nugax* (PILSBRY & FERRISS, 1906). Both were described from the Guadalupe River, Comal County, Texas, on the limestone-formed Edwards Plateau; PILSBRY (1916) assigned them to *Hauffenia*. The only other published American localities of the group are underground waters at San Marcos, Hays County, Texas; and near Fort Payne, DeKalb County, Alabama (HUBBRIGHT, 1940).

The distribution of *Horatia* and *Coahuilix* is paralleled by Crustacea of the order Thermosbaenacea (MAGUIRE, 1965), and the cirolanid isopod *Speocirolana* (COLE & MINCKLEY, 1966).

*Coahuilix* TAYLOR, gen. nov.

**Diagnosis.** Shell minute ( $1.0 \times 0.5\text{--}0.6$  mm in adults), nearly planispiral, with  $2\frac{1}{4}$  whorls, 1 of which is embry-

onic. Right side nearly plane, with a deeply incised suture; left side with an umbilicus about  $\frac{1}{3}$  of total diameter. Aperture ovate,  $\frac{3}{4}$  as wide as high, flared all around in mature shells. Sculpture consists of raised riblets on the postembryonic shell, irregularly spaced with interspaces 1-5 times the width of the riblets.

**Type.** *Coahuilix hubbsi* TAYLOR, spec. nov.

Only the type species is included in the genus. It is known only from the type locality, in the valley of Cuatro Ciénegas, Coahuila, México. The riblet-sculpture and apertural flare, especially, set this minute snail off from all other Horatiini.

The name is derived from Coahuila, and the Latin *helix*, *helicis*, feminine, a snail.

*Coahuilix hubbsi* TAYLOR, spec. nov.

(Text figures 8-13)

**Diagnosis.** Same as for the genus.

**Type.** UMMZ 220180. Coahuila, México: from a bottom sample of the northernmost pool of Pozos de la Berra, 14 km southwest of Cuatro Ciénegas. C. L. Hubbs, 6-IV-1961. The same collection yielded 15 other specimens; one is figured (UMZZ 220181), the others unfigured (UMMZ 220177). The locality is number 4 on Text figure 2.

Figure 8

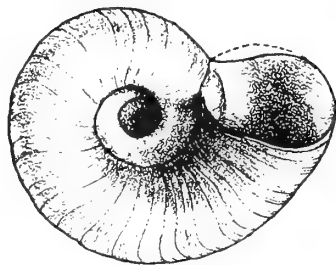


Figure 9

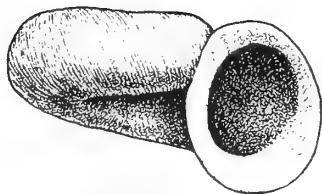


Figure 10

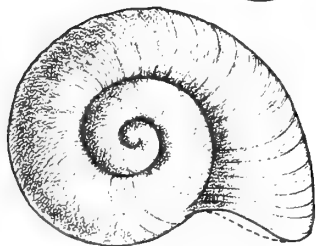


Figure 11

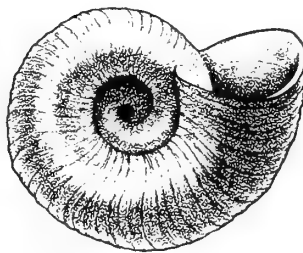


Figure 12

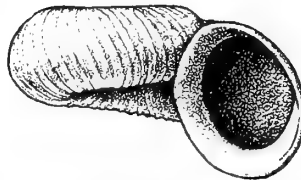
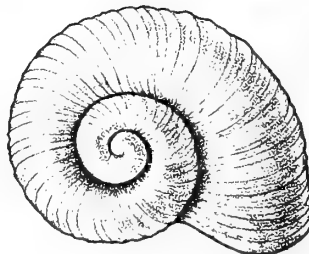


Figure 13



(For explanation see facing page)

**Description.** The shape of the shell is much like that of a low-spined *Valvata*. The right side is nearly plane, with the outer lip only a little to the left of the plane of the right side of the first whorl; on this side the convex whorls are separated by a deeply incised suture. The whorls are oval in cross-section, and increase in height more rapidly than in width, so that the left side shows a deep umbilicus about  $\frac{1}{3}$  the diameter of the shell. The aperture is ovate or almost perfectly elliptical, more than  $\frac{3}{4}$  as wide as high, and flared all around in mature shells. The inner lip is simply appressed to the preceding whorl. Sculpture on the postembryonic shell consists of slightly sinuous, irregularly spaced, prosocline riblets separated by spaces 1-5 times as wide.

The 5 mature and unbroken specimens measure as follows (mm):

Width	Height	Width aperture	Height aperture	No. of whorls
1.08	.64	.36	.40	2 $\frac{1}{4}$
1.04	.56	.36	.44	2 $\frac{1}{4}$ $\tau$
1.00	.56	.32	.36	2
1.00	.52	.36	.40	2 $\frac{1}{4}$ $\text{f}$
.96	.48	.32	.36	2 $\frac{1}{4}$

$\tau$ —Type

$\text{f}$ —Figured specimen

The 16 specimens are variously preserved, some broken or partly dissolved, others fresh-appearing. These latter seem to retain a nearly colorless periostracum. The strength of the riblets is uniform throughout the length of each riblet, but on some shells the riblets are worn or naturally weak.

The shells are so small that they might have been carried by current from their natural habitat, even from underground. If the relationships of this tiny snail are correctly interpreted, it is the most likely of all known species in the Cuatro Ciénegas area to be subterranean.

**Etymology.** The species is named in honor of Carl L. Hubbs, Scripps Institution of Oceanography, La Jolla, California.

#### Tribe *Clenchiellini*, new tribe

##### *Clenchiella* ABBOTT, 1948

*Carinorbis* YEN, 1946. Amer. Jour. Sci. 244: 46. Type (O.D.): *Carinorbis planospiralis* YEN. Not of CONRAD (1862).

*Clenchiella* ABBOTT, 1948. Nautilus 61: 76. Type (O.D.): *Clenchiella victoriae* ABBOTT.

*Carinulorbis* YEN, 1949. Jour. Paleont. 23: 573. New name for *Carinorbis* YEN.

Study of numerous early Tertiary fossils from Montana and Wyoming has revealed that most of the specimens

recorded as *Carinulorbis* belong to the Hydrobiidae rather than the Planorbidae, to which YEN referred his genus. The nearly straight growth lines, thicker shell, and large protoconch show these specimens are prosobranchs, not Planorbidae. The shallow suture, with overlapping whorls, and the more flat-walled umbilicus distinguish them from Valvatidae and show they are Cochliopinae. *Clenchiella planospiralis*, type of *Carinorbis*, is especially close to *Clenchiella* and no generic separation seems warranted.

The following species have been described:

*Clenchiella microscopica* (NEVILL, 1877) (*Valvata*?). Catalogue of Mollusca in the Indian Museum, fasc. E: 21. Port Canning, 24 Parganas District, West Bengal, India. So assigned by ABBOTT (1949).

*Clenchiella papuensis* JUTTING, 1963. Nova Guinea, Zool., 20: 438, text-figs. 6a-c. Robinson River Plantations near Cloudy Bay, east of Port Moresby, Papua, New Guinea.

*Clenchiella planospiralis* (YEN, 1946) (*Carinorbis*). Amer. Jour. Sci. 244: 46, pl. 1, figs. 6a-c. Arvada bed, Fort Union Formation, lower Eocene, Sheridan County, Wyoming. Known from the upper part of the Fort Union Formation and lower part of the Wasatch Formation, late Paleocene and earliest Eocene age, Powder River basin, Montana-Wyoming, U.S.A.

*Clenchiella sentaniensis* JUTTING, 1963. Nova Guinea, Zool., 20: 438, text-figs. 5a-b. Lake Sentani, western New Guinea.

*Carinulorbis utahensis* LA ROCQUE, 1960. Mem. Geol. Soc. Amer. 78: 38, pl. 3, figs. 23-26. Lower part of Flagstaff Formation, earliest Eocene, Sanpete County, Utah. From examination of the types, and from study of fossils of late Paleocene and Eocene age in Wyoming and Montana, this species is referred to *Valvata*. It is probably a synonym of *V. bicincta* WHITEAVES (1885).

*Clenchiella victoriae* ABBOTT, 1948. Nautilus 61: 76, pl. 5, figs. 1-7. San Joaquin River 2 miles north of Tanauan, Leyte Island, Republic of the Philippines. Known from one other locality also on the eastern coast of Leyte (ABBOTT, 1948).

MAPEL (1961: 72) recorded "*Carinorbis* sp." and "*Carinulorbis* sp. undet." from the Wasatch Formation in Johnson County, Wyoming. The specimens so identified are referred here to *Valvata*, probably an undescribed species related to *V. bicarinata* LEA. MAPEL's localities are stratigraphically higher than others at which *Clenchiella* has been found.

#### Figures 8 to 13

*Coahuilix hubbsi* TAYLOR, gen. et spec. nov.

Figures 8 to 10: Type, UMMZ 220180. Length 0.56 mm; width 1.04 mm; 2 $\frac{1}{4}$  whorls.

Figures 11 to 13: Figured specimen, UMMZ 220181. Length 0.52 mm; width 1.00 mm; 2 $\frac{1}{4}$  whorls.

**Fontigentinae TAYLOR, new subfamily**

Verge with 3 ducts: vas deferens, and 1 duct in each of 2 accessory processes on the left side of the verge. Operculum corneous, paucispiral.

**Referred genera:** Only the genus *Fontigens* PILSBRY, 1933, of eastern U.S.A. is included.

This new name is practically a substitute for *Emmericiinae* as used by MORRISON (1949). *Emmericia* lacks basal cusps on the central tooth of the radula, and is considered to belong to the *Micromelaniidae*, as classified by WENZ (1938-1944). The radula of *Fontigens* is similar to that of American *Hydrobiinae*.

***Fontigens* PILSBRY, 1933**

*Stimpsonia* CLESSIN, 1878. Malak. Blätt. 25: 151. Type (M): *Paludina nickliniana* LEA. Not of GIRARD (1853), nor BATE (1862).

*Fontigens* PILSBRY, 1933. Nautilus 47: 12. Type (O.D.): *Paludina nickliniana* LEA.

The strikingly distinctive male reproductive system has been described by F. C. BAKER (1928) and E. G. BERRY (1943); the latter has also described and illustrated the radula. The eggs and internal anatomy are unknown.

**Lithoglyphinae TAYLOR, new subfamily**

Shell globose or conic, 3.5-10 mm long, relatively thick and large for the family. Pigmentation usually consists not only of a dense suffusion of free melanin granules, but also larger yellow-pigment granules in the head-foot mass. The eyes are not in discrete swellings on the outer bases of the tentacles; but either in stout, tapering tentacles; with no swelling or basal peduncle, or on broad, buttress-like bases that are equally stout from the base of the tentacle to the eye. The verge is simple and blade-like, with no accessory glands or processes. The operculum is corneous and paucispiral, as in most *Hydrobiidae*.

**Referred genera:** *Lithoglyphus* HARTMANN, 1821 (including *Fluminicola* STIMPSON, 1865; *Heathilla* HANNIBAL, 1912; and *Pilsbryus* YEN, 1944).

A group name based on *Lithoglyphus* goes as far back as 1857 when TROSCHER (1856-1893) established a heterogeneous assemblage he called *Lithoglyphi*. TRYON (1866) and P.-H. FISCHER (1880-1887) both recognized a subfamily *Lithoglyphinae*, in each case of different scope but similarly heterogeneous. WENZ (1928) included *Lithoglyphus* by itself in the *Lithoglyphidae*, named but not defined. THIELE'S (1928) composite tribe "Lithoglyphaeae" is essentially WENZ'S (1938-1944) later *Lithoglyphinae*. Even after separating the *Delavayidae* from this assemblage (TAYLOR, 1966a) there is still a mixture of

*Hydrobiidae* remaining. The only other names based on genera of *Lithoglyphinae* are *Fluminicolinae* CLESSIN (1880), a heterogeneous group; and *Fluminicolidae* HANNIBAL (1912), named but not defined.

**Littoridininae TAYLOR, new subfamily**

Shell turritiform to elongate-conic; smooth to lirate, plicate, cancellate, or spinose. Operculum corneous; paucispiral and coiled in one plane (except in some aberrant genera of Lake Titicaca, Perú). Verge arising in the midline, or slightly to the right or left of the midline; coiled first posteriorly, or posteriorly and to the right, counter-clockwise through 180 to 360 degrees. Ornament on the verge consists of 2-10 bulbous or elongate lateral lobes, narrower at their attachment; all or some of these are often on the right side. Vas deferens nearly in the midline of the verge, opening through a terminal papilla.

The distinctive verge in this group is known in a small percentage of the American species, so that they seem to form a natural group.

**Referred genera** (see distribution map, Text fig. 14):

*Brachypyrulina* HAAS, 1955a. Lake Titicaca, Perú (1 species).

*Durangonella* MORRISON, 1945. Central México (5 species).

*Ecpomastrum* HAAS, 1957. Lake Titicaca, Peru (1 species).

*Heligmopoma* HAAS, 1955a. Lake Titicaca, Peru (1 species).

*Idiopyrgus* PILSBRY, 1911. Northeastern Brasil (4 species).

*Littoridina* SOULEYET, 1852. Western and southern South America, from Ecuador and the Lake Titicaca region of Peru southward and eastward to southern Brasil, Patagonia, and Chile (about 60 species).

*Littoridinops* PILSBRY, 1952. East coast of U.S.A., and Bahamas? (3 species); eastern Mexico? (1 species).

*Lyrodes* DOERING, 1884. Northeastern Argentina—southeastern Brasil (about 5 species).

*Mexipyrgus* TAYLOR, gen. nov. Valley of Cuatro Ciénegas, Coahuila, México (6 species).

*Pyrghophorus* ANCEY, 1888. Islands and margins of the Gulf of Mexico and Caribbean Sea. Early Pliocene—Recent (of 40 nomenclatural units probably only 10-15 are valid species).

*Rhamphopoma* HAAS, 1955a. Lake Titicaca, Peru (2 species).

*Strombopoma* HAAS, 1955a. Lake Titicaca and Lagunilla Lagunilla, Peru (2 species).

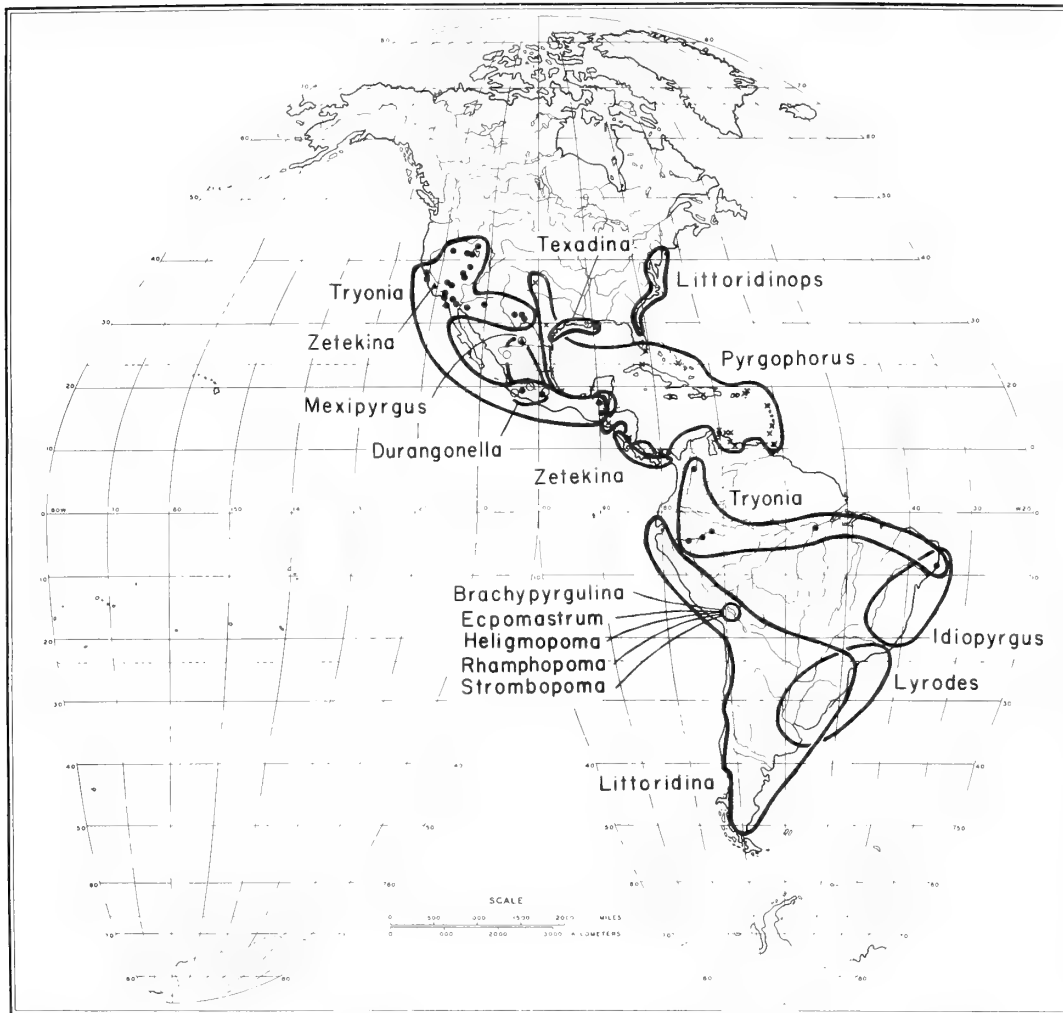


Figure 14  
Distribution of subfamily Littoridininae of family Hydrobiidae.

*Texadina* ABBOTT & LADD, 1951. Southeastern Texas and Louisiana, U.S.A. (1 species).

*Tryonia* STIMPSON, 1865. Great Basin region of western U.S.A. southward to Guatemala and northeastern Brasil; fossil in Colombia and the upper Amazon region, Brasil-Peru. Late Oligocene or early Miocene to Recent (about 16 species).

*Zetekina* MORRISON, 1947. Pacific drainage of Nicaragua and Panamá, and Pearl Islands, Panamá (7 species); late Pliocene, California, U.S.A. (1 species).

The Littoridininae as defined here are a taxonomically new group, in that new characters have been used to define it and the scope of the assemblage is novel. Group names have been based on genera included herein, but on different grounds. F. C. Baker (1928: 144) suggested that a family Potamopyrgidae might be warranted for the ovoviviparous, spiny-shelled snails now included in *Potamopyrgus* and *Pyrgophorus*. THIELE (1928) established a tribe Littoridineae in the Hydrobiidae, using features of the radula. This group, raised by WENZ (1939) to subfamily rank, seems heterogeneous when other characters are taken into account.

Subdivision of the Littoridininae is impracticable on account of lack of knowledge. The spinose shell and ovoviviparous reproduction of *Pyrgophorus* and *Potamopyrgus* have been taken to indicate affinity. Yet the verge of *Potamopyrgus* as described by MORRISON (1939a) is simple, unlike the ornamented structure of *Pyrgophorus*; and STIMPSON (1865) and MORRISON (1939a) described the eyes of *Potamopyrgus* as borne on prominent tubercles. These differences indicate the likelihood *Potamopyrgus* is not close to the American forms. In spite of the differences in mode of reproduction, operculum, shell form and sculpture, the American Littoridininae seem a well-knit group according to characters of radula, verge, pigmentation, and relation of eyes to tentacles.

#### *Brachypyrulina* HAAS, 1955

Trans. Linn. Soc. London, ser. 3, 1: 301. Type (O. D.): *Brachypyrulina carinifera* HAAS.

The shell is elongate-conic, shorter and broader than that of *Littoridina* and similar to *Heligmopoma* in proportions, but bicarinate. The paucispiral operculum has an internal subspiral corneous callus.

*Brachypyrulina carinifera* HAAS, 1955. Trans. Linn. Soc. London, ser. 3, 1: 301, text-fig. 27. Lake Titicaca, Perú.

#### *Durangonella* MORRISON, 1945

Nautilus 59: 18. Type (O. D.): *Durangonella seemani* (FRAUENFELD).

Shell turriform to aciculate, with 5-8 whorls separated by an incised suture, oval in cross-section. Sculpture consists only of growth lines. The verge has 2 short accessory lobes on the left, toward the distal end.

This group combines characters found in otherwise dissimilar genera. The shell is much like that of smooth species of *Tryonia*, but more elongate and narrow. The verge is more like that of *Zetekina*, a genus with markedly different shell.

Four species have been assigned to *Durangonella* by MORRISON (1945). Localities of these four and a new species described herein are shown on Text figure 15.

*Durangonella dugesiana* MORRISON, 1945. Nautilus 59: 21, pl. 3, fig. 3. Subfossil, "near Andocutira," Michoacán, México.

The index of the American Geographical Society's Map of Hispanic America, 1:1,000,000, lists no place called Andocutira. There is an Andocutin, in the state of Guanajuato near the border of Michoacán, and so this seems most likely to be the type locality.

*Durangonella mariae* MORRISON, 1945. Nautilus 59: 20, pl. 3, fig. 2. Subfossil, dry bed of lake at Tlahuac, 20 km east of Xochimilco, D. F., México.

*Durangonella pilsbryi* MORRISON, 1945. Nautilus 59: 22, pl. 3, fig. 4. Paso del Río, Colima, México.

*Durangonella seemani* (FRAUENFELD, 1863) (*Hydrobia*). Verhandl. k. k. zool.-bot. Gesellsch. Wien 13: 1025. Durango, México.

#### *Durangonella coahuilae* TAYLOR, spec. nov.

(Plate 14, Figures 19, 22)

**Diagnosis.** Shell 3.0-3.5 mm long, with about 5½ whorls. It differs from the similar *D. mariae* MORRISON by its more nearly circular aperture, more concave columellar lip, less deeply impressed and more slowly descending suture. **Type.** UMMZ 220159. Coahuila, México: Laguna Grande, in the middle of the east side, within about 300 m of the mouth of Río Churince, and about 17 km southwest of Cuatro Ciénegas. D. W. Taylor, 14-IV-1965. Other specimens are UMMZ 220160 (figured specimen) and 220158. The species is known for certain only from Laguna Grande (Text figure 2, locality 10).

**Discussion.** The specific differences are finely drawn in shells of *Durangonella*, but the known localities are so widely scattered in México (Text figure 2) that they are likely all valid forms. By analogy with the other prosobranch snails from the valley of Cuatro Ciénegas at least 1 species in *Durangonella* would seem to be new. There is no standard by which to judge variation in different pop-

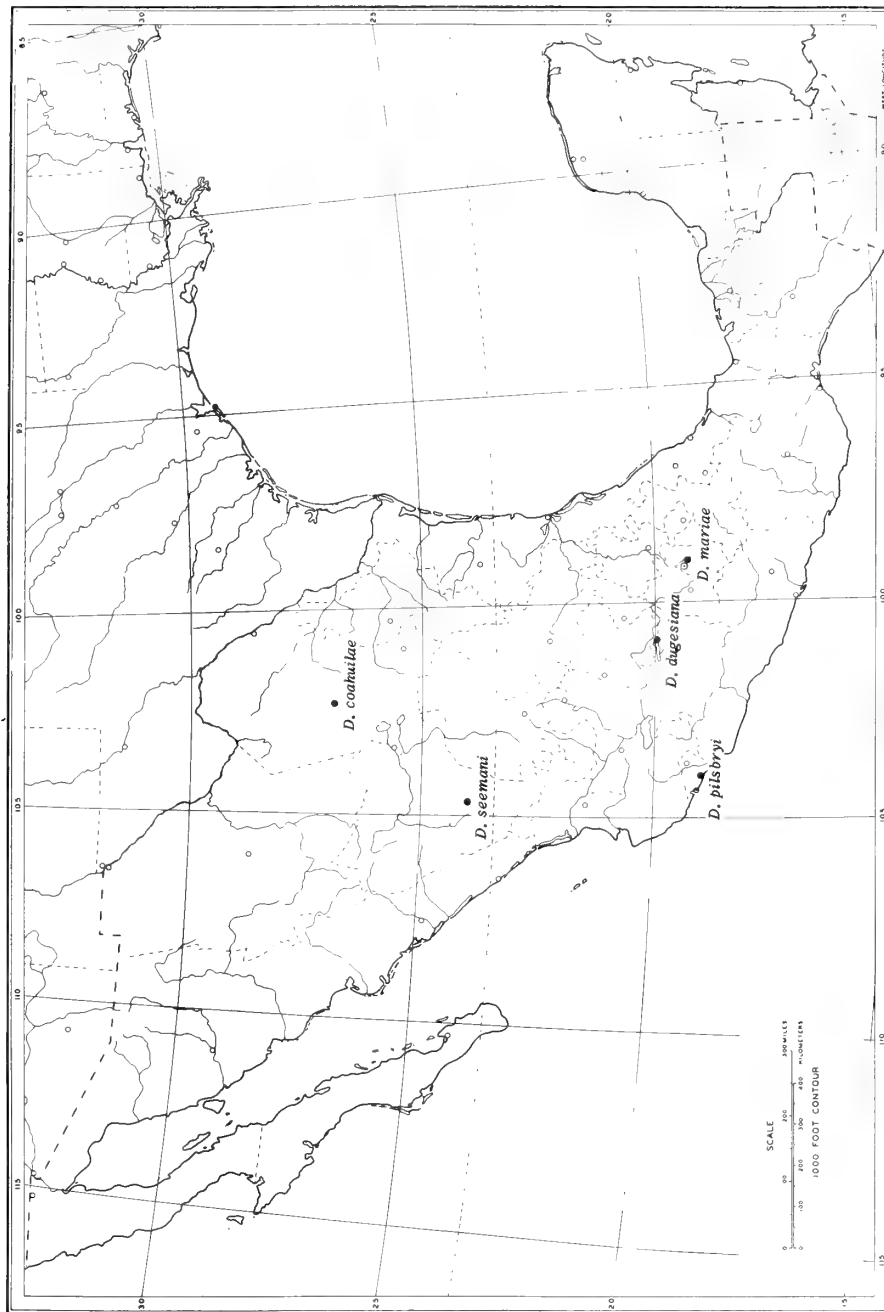


Figure 15  
Distribution of *Durangonella*.

ulations of a single species, hence other occurrences of *Durangonella* in the vicinity may or may not represent this species.

Habitat: See p. 164.

Etymology. The species is named for its occurrence in the state of Coahuila.

*Durangonella* spec.

(Plate 14, Figures 20, 21)

Empty shells of *Durangonella* were found at 2 localities. They probably represent a new species, but I think it is unwise to name another form geographically so close to *D. coahuilae* without knowing more of the range of variation of the species, or trying to collect living specimens. Localities and material examined. Río Mesquites, 9 km SW Cuatro Ciénegas; D. W. Taylor, 13-IV-1965 (UMMZ 220190). Spring tributary to El Mojarral, 1.7 km due east of the northern tip of Sierra de San Marcos, 11 km SW of Cuatro Ciénegas; W. L. Minckley, 13-IV-1965 (UMMZ 220161; 220162, figured specimens).

*Durangonella?* spec.

Bleached, perhaps subfossil shells that might be *Durangonella* were collected by H. V. Anderson at Laguna de Viesca, Coahuila (USNM, uncatalogued). They might represent part of the fauna of a former lake in that basin.

*Ecpomastrum* HAAS, 1957

Arch. Molluskenk. 86:137. Type (O. D.): *Ecpomastrum mirum* HAAS.

The loosely coiled, corkscrew-like shell is more like the shells of Littoridininae than those of other Hydrobiidae in South America. The genus is known from only 1 shell, lacking the operculum.

*Ecpomastrum mirum* HAAS, 1957. Arch. Molluskenk. 86:137, text-figs. 1-2. Lake Titicaca, Peru.

*Heligmopoma* HAAS, 1955

Trans. Linn. Soc. London, ser. 3, 1: 300. Type (O. D.): *Heligmopoma umbilicatum* HAAS.

The shell is elongate-conic, shorter and broader than that of *Littoridina*. The paucispiral operculum has the edges of its whorls raised as lamellae above the outer surface, though not approaching the extreme of *Strombopoma*.

*Heligmopoma umbilicatum* HAAS, 1955. Trans. Linn. Soc. London, ser. 3, 1: 300, text-fig. 26. Lake Titicaca, Peru.

*Idiopyrgus* PILSBRY, 1911

Rep. Princeton Univ. Exped. Patagonia 1896-99 3: 564. Type (O. D.): *Idiopyrgus souleyetianus* PILSBRY.

*Hydracme* HAAS, 1938. Arch. Molluskenk. 70: 46. Type (O. D.): *Hydracme rudolphi* HAAS.

The narrow, turritiform shell is similar to many other Littoridininae in general shape, but differs by the internally thickened aperture, the anteriorly prolonged outer lip, and the sometimes bisinuate growth line.

Four species have been described; all are from northeastern Brasil.

*Idiopyrgus pilsbryi* F. BAKER, 1913. Proc. Acad. Nat. Sci. Philadelphia 65: 658, pl. 26, figs. 13-14. North bank of chief affluent of Papary Lake near its mouth, State Rio Grande del Norte, Brasil.

*Idiopyrgus rudolphi* (HAAS, 1938) (*Hydracme*). Arch. Molluskenk. 70: 46, text-fig. 4. Río São Francisco near Jatobá, State Pernambuco, Brasil.

*Idiopyrgus souleyetianus* PILSBRY, 1911. Rep. Princeton Univ. Exped. Patagonia 1896-99 3: 565, pl. 41C, figs. 14, 14a; text-fig. 12. Rio Doce, State Espirito Santo, Brasil.

*Idiopyrgus walkeri* PILSBRY, 1924. Proc. Acad. Nat. Sci. Philadelphia 76: 59, text-fig. 9. Rio de Valhas, trib-

## Explanation of Plate 14

Snails from the Valley of Cuatro Ciénegas, Coahuila.

Figure 18 by J. Tottenham, others by K. Sakamoto.

Figure 18: *Physa virgata* GOULD. Figured specimen, UMMZ 220217. Length 7.1 mm, width 4.2 mm,  $4\frac{1}{2}$  whorls.

Figures 19, 22: *Durangonella coahuilae* TAYLOR, spec. nov. 19. Figured specimen, UMMZ 220160. Length 3.7 mm, width 1.4 mm, 6 whorls.

22. Type, UMMZ 220159. Length 3.3 mm, width 1.4 mm,  $5\frac{3}{4}$  whorls. Figures 20, 21: *Durangonella* spec.

25, 26. Figured specimen, male, UMMZ 220203. Length 4.2 mm, width 2.1 mm,  $5\frac{1}{2}$  whorls.

20. Figured specimen, UMMZ 220162. Length 4.8 mm, width 1.6 mm,  $7\frac{3}{4}$  whorls.

21. Figured specimen, UMMZ 220162. Length 5.9 mm, width 1.8 mm, 9 whorls.

Figures 23 to 26: *Mexipyrus escobedae* TAYLOR, spec. nov.

23, 24. Type, female, UMMZ 220202. Length 4.5 mm, width 2.5 mm,  $5\frac{3}{4}$  whorls.





Figure 18

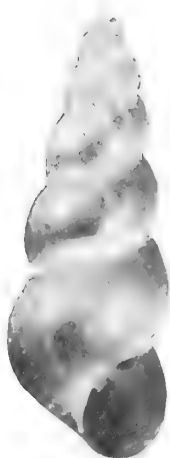


Figure 19



Figure 22



Figure 20



Figure 21

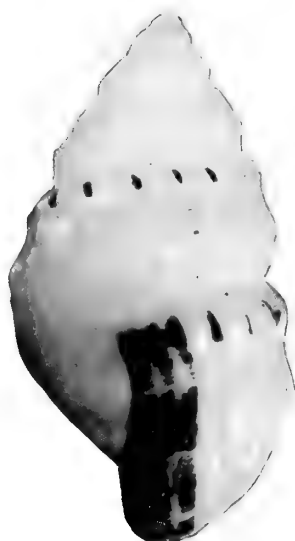


Figure 23



Figure 24



Figure 25



Figure 26



utary to Rio San Francisco, at Lassance, State Minas Geraes, Brasil.

*Hydracme rudolphi* HAAS (1938) was based on a series of specimens taken from a fish stomach. A larger series of topotypes, fresh-appearing but rarely retaining the operculum, is catalogued as UMMZ 64012. The variation within this series, and among other lots representing undescribed species from the states Paraiba and Pernambuco, effaces the supposed distinctions between *Hydracme* and *Idiopyrgus*. The sutures may be incised and the whorls convex, but variation is continuous to include a flat-sided spire with scarcely impressed sutures. Details of shape of the aperture also vary from a smaller heavily callused aperture that is straight in profile and inclined slightly to the axis of the shell, to a larger, flared, bisinuate aperture that is less heavily thickened and diverges more from the shell axis.

#### *Littoridina* SOULEYET, 1852.

EYDOUX, J. F. T., and L. F. A. SOULEYET, Voyage autour du monde . . . sur la corvette La Bonite, 1836-1837, Zoologie, 2: 563. Type (M): *Littoridina gaudichaudii* SOULEYET, 1852.

*Heleobia* STIMPSON, 1865. Smithson. Misc. Coll. 201: 47. Type (perhaps M.; probably S. D. by PILSBRY, 1911): *Littoridina culminea* (D'ORBIGNY).

The most thorough account of the anatomy of *Littoridina* is that by SOULEYET (1852). Most of the characters he described cannot be evaluated on account of lack of information about other species. *Littoridina gaudichaudii* agrees with the species described by HUBENDICK (1955) in having the eyes on low swellings of the lateral bases of the tentacles; a diffuse pigment pattern with no well defined bands; and oviparous reproduction. It differs in the verge, that has digitate appendages on both sides, an origin to the right of the midline of the body, a vas deferens slightly to the right of the midline in the verge, and the opening of the vas deferens to the left of the terminal papilla. Without knowing the quality of the material studied by SOULEYET (whether living, or preserved in formalin, strongly contracted or not) it is difficult to tell how much reconstruction is included in the drawings. The presence of ornament on the left side of the verge is a real and probably significant difference from the species described by HUBENDICK (1955), but the other differences may be only apparent. So far as the descriptions by IHERING (1895) can be compared, they agree with that of *L. gaudichaudii*.

Subdivision or separation of *Littoridina* will not rest on a firm foundation until at least the gross morphology of many more Recent species is known. Accordingly *Heleobia* is best left as a synonym.

No thorough summary of the South American species of *Littoridina* has been attempted. PILSBRY (1911) brought together all available information through 1909. Later knowledge is due mainly to BIESE (1944, 1947), HAAS (1955a) and HUBENDICK (1955).

#### *Littoridinops* PILSBRY, 1952

Nautilus 66: 51. Type (O. D.): *Amnicola tenuipes* COUPER, in HALDEMAN, 1844.

The shell is narrowly elongate, without sculpture except for growth lines, and not significantly distinguishable from shells of *Littoridina*, or even smooth forms of *Pyrgophorus*. The verge differs more from that of *Littoridina* than do those of *Littoridina* and *Pyrgophorus*, so that generic rank seems appropriate. In *L. tenuipes* as described by PILSBRY (1952) there are 5 elongate appendages at the base of the verge on the left side, and about 6 long and several short ones near the tip, on both sides. That species is oviparous.

The known species are found in brackish and fresh water along the east coast of the U. S. A. from New York to Florida; perhaps on Andros Island, Bahamas; perhaps in San Luis Potosí, México.

*Littoridinops? blacki* (PILSBRY, 1930) (*Hydrobia*). Proc. Acad. Nat. Sci. Philadelphia 82: 301, pl. 22, fig. 4-6. Lake Forsyth, Andros Island, Bahamas. Referred questionably to *Littoridina* by PILSBRY (1950).

*Littoridinops? monroensis* (FRAUENFELD, 1863) (*Hydrobia*). Verhandl. k. k. zool.-bot. Gesellsch. Wien 13: 1023. Lake Monroe, Florida. Referred questionably to *Littoridina* by PILSBRY (1899).

*Littoridinops? tampicoensis* (PILSBRY & HINKLEY, 1907) (*Paludestrina*). Nautilus 21: 39, pl. 5, fig. 13. River debris at Tampico, San Luis Potosí, México. Described as related to *L. monroensis*, and not close to other Hydrobiidae of México or Texas.

*Littoridinops tenuipes* (COUPER), in HALDEMAN, 1844 (*Amnicola*). Monog. limniades, pt. 7, p. 4 of cover. Hope-ton, on Altamaha River 5 miles above Darien, Georgia. PILSBRY (1952) gave the distribution as "Lower Hudson Valley, New York, to Florida."

#### *Lyrodes* DOERING, 1884

Bol. Acad. Nac. Ci. Córdoba 7: 461. Type (S. D.): PILSBRY, 1911): *Lyrodes guaranitica* DOERING, 1884.

Both the unity and the rank of the Argentine-Braslian *Lyrodes* are questionable in the lack of anatomical knowledge. The spinose sculpture so common in *Pyrgophorus* (in both fresh and brackish-water habitats) is unknown south of the margins of the Caribbean Sea, so that it is unlikely these groups are congeneric. Possibly *Lyrodes* will

turn out to be a synonym of *Tryonia*, but shells of the latter are generally more narrowly elongate.

Three species of *Lyrodes* from Argentina and southern Brasil were reviewed by PILSBRY (1911), who found 2 embryonic young in a specimen of *L. peteningensis* (GOULD), and 1 in a specimen of *L. scottii* (PILSBRY). More recently named species can be traced through the paper by PARODIZ (1960).

HAAS (1952, 1955b, 1955c), described "*Potamopyrgus*" *subgradatus* from the state of Pará, northeastern Brasil. This might be a *Lyrodes*, if that is a valid group, but cannot be allocated with probability to any genus and is considered here incertae sedis.

### *Mexipyrus* TAYLOR, gen. nov.

**Diagnosis.** Shell elongate-conic to turritiform, with conspicuous sexual dimorphism, 4.5-7.2 mm long in adults, anomphalous, with  $5\frac{1}{2}$ -7 whorls. Body whorl nearly smooth or with reticulate sculpture; a peripheral keel with nodes usually present at about 3-4 whorls. Periostracum with about 3-20 spiral dark brown bands usually related to surface sculpture. Growth lines prosocyr, with the most distal point below the periphery. Operculum plane, corneous, paucispiral. Verge with a broad, transversely wrinkled base narrowing to a distal, melanin-pigmented bulbous end with a terminal papilla; ornament consisting of 2-3 narrowly pyriform processes, 1-2 on the left side at the distal end and 1 on the right side at  $\frac{3}{4}$  of the verge length.

**Type.** *Mexipyrus carranzae* TAYLOR, spec. nov.

**Distribution.** The genus is known only from the valley of Cuatro Ciénegas, central Coahuila, México. Within this area local differentiation is remarkable. The following forms are named herein:

*Mexipyrus carranzae* TAYLOR, spec. nov. Laguna Tío Candido.

*Mexipyrus churinceanus* TAYLOR, spec. nov. Laguna Churince, Pozos de la Becerra.

*Mexipyrus escobedae* TAYLOR, spec. nov. Laguna Escobeda.

*Mexipyrus lugoi* TAYLOR, spec. nov. Río Mesquites.

*Mexipyrus mojarrales* TAYLOR, spec. nov. West Laguna in El Mojarrales.

*Mexipyrus multilineatus* TAYLOR, spec. nov. East Laguna in El Mojarrales.

**Etymology.** The name is derived from México, and the Greek word *pyrgos*, a tower.

Differentiation within *Mexipyrus*.

In some ways the discovery of distinct species that are found as single local colonies in the valley of Cuatro Ciénegas is the most interesting aspect of the fauna there.

More study of the known colonies, the search for others, and determining the precise limits of distribution will be necessary for any real advance in knowledge. Yet even at this stage a few observations and inferences are worth while.

The morphological similarities and differences are not correlated consistently with geographic distribution. Some nearby populations (*M. churinceanus* in Laguna Churince and Pozos de la Becerra; *M. lugoi* in Río Mesquites) are generally similar, but others are not (*M. mojarrales* and *M. multilineatus*, within 0.3 km). *Mexipyrus mojarrales* in El Mojarrales is most like *M. churinceanus*, from the other side of Sierra de San Marcos. The mixtures of similar and different characters found in each species are suggestive evidence that these forms have diverged through the assortment of characters. No one form is likely to have evolved from any other one.

Color banding is rare within the Hydrobiidae, and is unknown in the subfamily Littoridininae except for *Mexipyrus*. One may well ask whether such a striking feature is not an adaptation, perhaps influenced by predatory fishes. My contribution of knowledge is minor. All *Mexipyrus* are found within a soft oozy substratum, and are invisible above the surface. There is no chance that the banding is associated with direct visual predation by the fishes, although one cannot exclude a more complicated relationship of color and predation.

Such local species within the genus *Mexipyrus* lead immediately to a search for isolating mechanisms. More field work will be needed to define the colonies and help establish degrees of relationship, but even from a brief visit it seems that the habitat of this genus is more likely to be discontinuous than that of other snails in the area. *Mexipyrus* lives in soft flocculent ooze or mud in the lagunas, thus not in the shallows where wave action removes the fine particles. Extensive marshy areas with small streams connecting larger water bodies provide no suitable widespread habitat.

A particularly striking observation on speciation in this group is that none of the colonies differing in shape, sculpture, size, and banding show corresponding differences in the pattern of the verge. Details of ornament (accessory processes, glandular areas, and the like) of the verge are a prolific source of useful characters in this family. In the genus *Fontelicella* (GREGG & TAYLOR, 1965) of the Hydrobiinae, different colonies within 1 species ordinarily show slight differences in pattern of ornament of the verge, and there are always differences in this organ from species to species. From this experience I expected to find, and looked specially for, similarly characteristic patterns of the verge appendages, shape, pigmentation, and the like. Virtually all of the species have a uniform verge; hence I

suspect that the divergence of the various populations of *Mexipyrgus* may have had nothing to do with reproductive isolation, except through geographic separation.

#### Description of *Mexipyrgus*

**Shell.** The shell is elongate-conic to turritiform, reaching a maximum size of about 4.5-7.2 mm with  $5\frac{1}{2}$ -7 whorls according to the species. Sexual dimorphism is marked, perhaps in correlation with ovoviviparity, so that females are generally more broadly conical than males. Doubtless there are differences in proportions of shell between the various species, but considerable biometric analysis of sexed specimens will be necessary to distinguish the effects of different proportions of males and females, different degrees of dimorphism, and differences between samples of one sex. Diagnoses of the species make practically no mention of proportions of the shell for this reason.

The aperture is elongate-ovate, narrower posteriorly, with a continuous border simply appressed to the preceding whorl. In some adults it may be slightly loosened from the preceding whorl. In profile the outer lip is strongly prosocyr, with the most distal point anterior to the periphery of the whorl. There is no umbilicus.

Sculpture includes both spiral and axial elements. At low magnifications the first whorl appears smooth. Subsequent sculpture begins as a peripheral carina or thread on the second whorl. This carina is usually the dominant element of sculpture for the next 2 whorls, and may persist or disappear thereafter. Other spiral threads may be added subsequent to the peripheral carina. Axial sculpture appears at the second to third whorl as short ribs that form nodes on the spiral carina. The ribs may persist or disappear on the body whorl. The details of ontogeny of sculpture include important criteria for separating species and are mentioned in the diagnoses. In all species the body whorl has a prominent spiral swelling anterior to the suture; this is described as a subsutural cord if narrow, and as a welt if broader and more swollen. This subsutural welt develops in the last 2-3 whorls. Next anterior to the welt is a broad shallow groove, more prominent when the welt is more prominent, bordered anteriorly by a low peripheral cord or an indistinct boundary. This peripheral cord, not always present, is the continuation of the carina of the early whorls.

Color banding of the periostracum varies greatly between species. Frequently there is a broader band, or a group of bands, or a more usually present narrow band on the subsutural welt. Other color bands are often on spiral cords.

**Head-foot mass.** The foot is truncate in front, broadly rounded behind, with 2 auriculate lobes at the anterior corners that are set off from the posterior parts by shallow

indentations of the sides. The operculigerous lobe is bordered by a shallow, indistinct groove.

The snout is long and tapering, with the buccal mass close to the anterior end. The lips are on the ventro-anterior aspect, and relatively small (about half the area of the anterior end of the snout). They are semicircular to reniform, closer together dorsally, and set off from the snout by a narrow incised groove.

The tentacles are about  $\frac{2}{3}$  as high as they are wide, blunt-tipped and not obviously tapering. No discrete ciliary tracts are present; the uniformly distributed cilia are no longer than elsewhere. The eyes lie in the outer bases of the tentacles, in low, indistinct swellings.

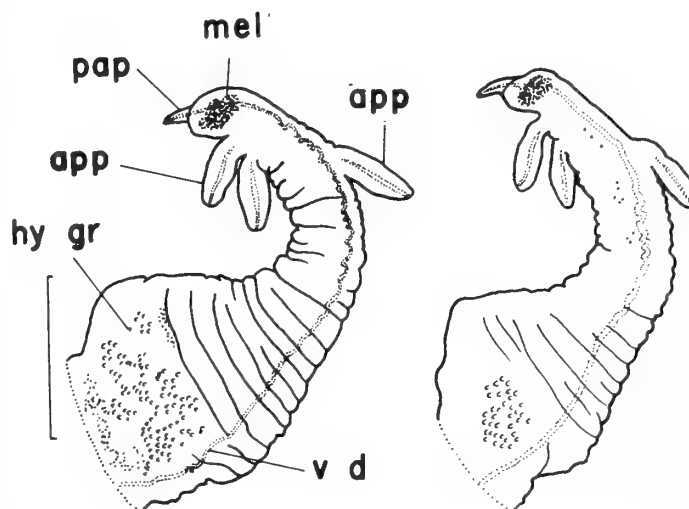


Figure 16

Verges of *Mexipyrgus carranzae* TAYLOR, gen. et spec. nov., dorsal view; scale line = 1 mm. app - appendages; hy gr - hyaline granule; mel - melanin pigment; pap - papilla.

**Verge** (Text figure 16). The verge has a broad insertion, extending from a little left of the median plane to a little right of a sagittal plane through the base of the right tentacle. It consists of a large penis with 3 elongate appendages, narrower at their attachment than in the middle. An intensely melanin-pigmented area forms a short cylinder within the terminal bulb of the penis. The terminal bulb is heavily ciliated, the cilia being longer there than posteriorly, but the papilla is not ciliated so heavily.

In life the verge is borne curving to the left  $90^\circ$  -  $180^\circ$ , with the long shaft heavily, transversely wrinkled. The appendages are clear, unwrinkled, circular in cross-section, and without ornament. Each has a central lumen opening externally.

*Mexipyrgus carranzae* TAYLOR, spec. nov.

(Plate 15, Figures 27 - 32; Text-figure 16)

**Diagnosis.** One of the larger species of *Mexipyrgus*, attaining a length of 7.0 - 7.2 mm with  $6\frac{1}{2}$  -  $6\frac{3}{4}$  whorls. A peripheral carina develops on the second or third whorl, and may persist as a dominant spiral element through the fourth whorl. Other relatively strong threads develop on the third and later whorls, and may become as strong as the peripheral cord. A subsutural cord develops on the antepenultimate whorl and becomes a strong cord or even a welt on the body whorl; it is stronger than the peripheral cord. Axial ribs develop on the second or third whorl, and form nodes where they cross the spiral cords. On the body whorl sculpture is cancellate, with the ribs dominant; the numerous spiral cords and fine spiral threads usually weaken or are interrupted as they cross the ribs. The periostracum has 6 - 8 wide brown bands, each on a cord, with a few variable fine bands intercalated. The widest band lies on the subsutural cord; the peripheral band may be but is not always wider than the others. The ground-color of the periostracum varies from light to dark brown, so that the dark brown bands vary in contrast.

**Type.** UMMZ 220211. Coahuila, México: Laguna Tío Candido, 14 km south of Cuatro Ciénegas. D. W. Taylor, 15 - IV - 1965. Others from the same collection are UMMZ 220212 (figured specimens) and 220213. The species is known only from this laguna (Text figure 2, locality 8).

**Comparison.** *Mexipyrgus carranzae* is like *M. escobedae* in having axial ribs dominant on the body whorl, but the spiral cords are much stronger in *M. carranzae* so that the general pattern is cancellate. It differs further by its larger size, fewer and more distinct bands, by the relatively weaker subsutural cord, and the ontogenetically earlier appearance of the subsutural cord.

**Habitat.** See p. 163 and Pl. 12, Fig. 9.

**Etymology.** The name is in reference to Cuatro Ciénegas de Carranza. The town was originally called simply Cuatro Ciénegas, but the name was later lengthened in honor of former President Carranza.

Venustiano Carranza (1859-1920) was born in Cuatro Ciénegas and began his political career as Presidente Municipal, to which office he was elected in 1887 and 1894. He rose to become President of México, 1917-1920.

**Pigmentation.** The testis appears pink through the shell, when visible, but heavily banded shells may not reveal it. When the shell is broken away the testis can be seen to be brilliant red-orange, in contrast to that of the paler *Mexipyrgus escobedae*.

The operculum is darker than in *Mexipyrgus escobedae* but details of pigmentation and the attachment of the operculum are nevertheless readily visible through it. White-appearing hyaline granules are more concentrated in the columellar area beneath the operculum than they are in *M. escobedae*. As in that species they are conspicuous by contrast with the black, melanin-pigmented area under the operculum.

In gross external appearance the body appears pale gray except for the dark ventral part of the foot and the black area beneath the operculum. Pigmentation is heavier over-all than in *Mexipyrgus escobedae*. Melanin occurs throughout most of the foot, in general deep to the sole, and dominates the white hyaline granules. The skin of the dorsal and dorsolateral surfaces of the snout is lightly dusted with melanin, not clear as in *M. escobedae*. The buccal mass appears pale reddish, and is visible indistinctly. The tentacles lack melanin; their only color is given by a few scattered hyaline granules. The sides of the body-stalk usually lack melanin, so that there are two separate dark areas; one in the area between and just behind the tentacles; the other in the edge of the foot, fading out dorsally. The mantle edge in *M. carranzae* is more heavily pigmented than that of *M. escobedae*, and has a salt-and-pepper appearance due to mixed melanin and hyaline granules.

Hyaline granules in the side of the foot appear yellow in lateral view, from the sole up to behind the tentacles. There is no concentration around the eyes to form "eyebrows," but scattered granules occur in the tentacles.

*Mexipyrgus churinceanus* TAYLOR, spec. nov.

(Plate 16, Figures 33-39; Plate 17, Figures 40-41)

**Diagnosis.** One of the larger species of *Mexipyrgus*, attaining a length of 6.5 - 7.0 mm with 7 whorls. A peripheral carina develops on the second whorl and is the dominant spiral element on the third to fourth whorls; it may persist on the body whorl as an indistinct cord or

## Explanation of Plate 15

*Mexipyrgus carranzae* TAYLOR, spec. nov., from the Valley of Cuatro Ciénegas, Coahuila.

Photographed by K. Sakamoto.

27, 28. Figured specimen, male, UMMZ 220212. Length 6.3 mm, width 3.1 mm,  $6\frac{3}{4}$  whorls.

29, 32. Type, a female, UMMZ 220211. Length 6.8 mm, width 4.0 mm,  $6\frac{3}{4}$  whorls.

30. Figured specimen, a female, UMMZ 220212. Length 7.2 mm, width 3.7 mm,  $6\frac{3}{4}$  whorls? (tip eroded).

31. Figured specimen, male, UMMZ 220212. Length 6.6 mm, width 3.3 mm,  $6\frac{3}{4}$  whorls? (tip eroded).



Figure 27

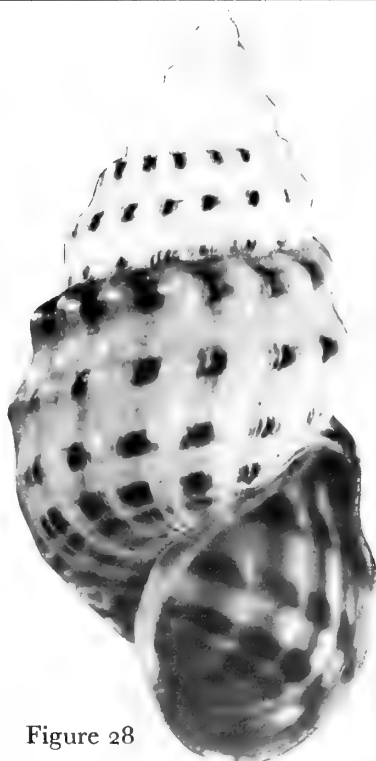


Figure 28

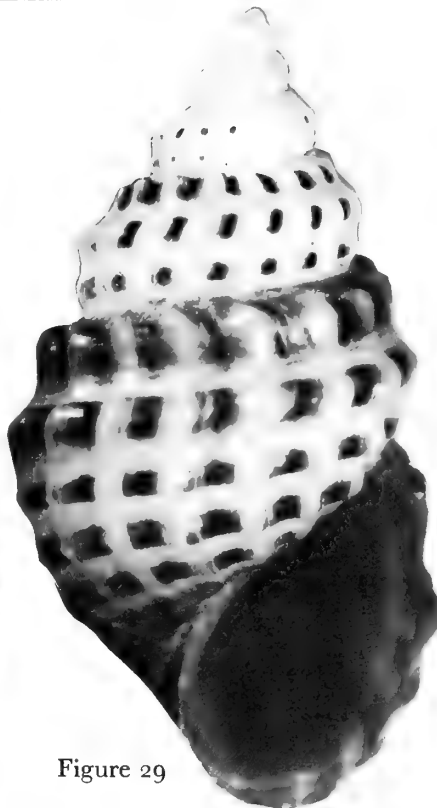


Figure 29

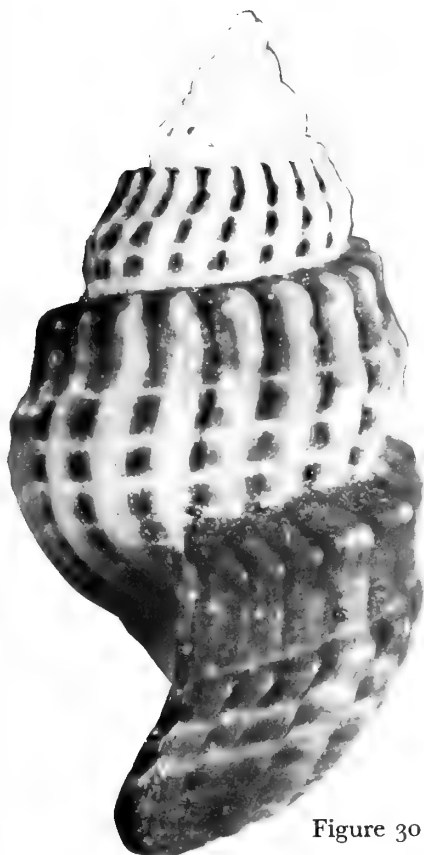


Figure 30

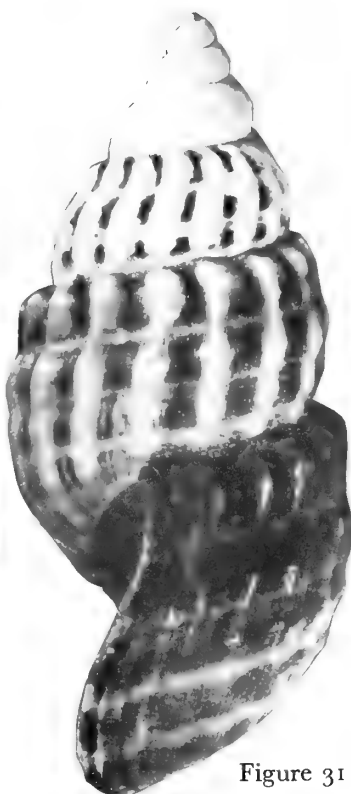


Figure 31

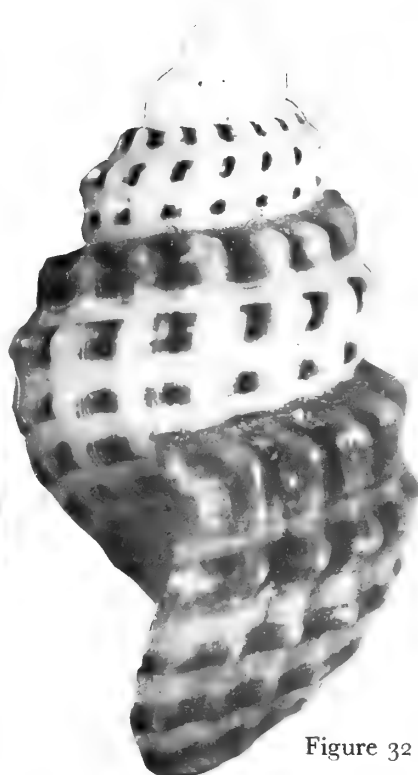


Figure 32





fade before then. A subsutural cord develops on the antepenultimate whorl and strengthens into a welt. Axial ribs developing on the third whorl form nodes where they cross the subsutural cord and peripheral carina, and may persist on the body whorl. On the body whorl spiral sculpture consists of a subsutural welt, variable fine threads, and usually a poorly defined low peripheral cord. Axial sculpture may consist only of growth lines, or well-defined collabral ribs may occur; commonly the ribs are weak and poorly defined, or represented by low nodes on the subsutural welt and the periphery. The periostracum has about 5 - 14 (8 - 10 common) sharply defined wide brown bands of variable spacing; fine bands may be intercalated. The subsutural welt is emphasized by one wide band or a group of nearly fused narrow bands. The periphery bears a band, but not an especially wide one. The ground-color of the periostracum varies from nearly colorless to light brown, so that the bands vary in contrast.

**Type.** UMMZ 220150. Coahuila, México: Laguna Churince, 16 km southwest of Cuatro Ciénegas. D. W. Taylor, 12 - IV - 1965. Others from the same collection are UMMZ 220151 (figured specimens) and 220149. The locality is number 3 on Text figure 2.

**Comparison.** *Mexipyrus churinceanus* is most similar in size and banding to *M. lugoi* from the Río Mesquites. It differs in the narrower diameter of the last whorls, so that the whole shell is narrower, the last whorl shorter and narrower, the aperture shorter, and the shell has 1 whorl more at the same length. *M. churinceanus* also has fewer, wider brown bands than in *M. lugoi*, and a subsutural wide band not found in the latter.

In some features of shape, sculpture, and banding *Mexipyrus churinceanus* is like *M. mojarrales* and *M. multilineatus*; the differences are discussed under those species.

**Referred specimens.** Not enough well-preserved specimens from Pozos de la Becerra (Fig. 2, locality 4) are available to study in the same detail as the other colonies of *Mexipyrus*. They are at least close to *M. churinceanus* even though showing some differences, and are referred tentatively to that species. Three empty shells retain traces of banding, and show a wide subsutural band with a few others that could be duplicated in *M. churinceanus* from the type locality. These specimens show that in pattern of banding as in shell sculpture the population at Pozos de la Becerra is most like that from Laguna Churince. A few snails with no shell color were collected alive at Laguna Churince, but to judge by the small sample there were many more unbanded shells at Pozos de la Becerra. This population is likely to become extinct in the near future if it is not already, and hence the precise relationship probably will never be determinable. Material examined (all from Pozos de la Becerra): C. L. Hubbs, 6-IV-1961

(UMMZ 220173); W. L. Minckley, 28-XII-1964 (UMMZ 220170); D. W. Taylor, 14-IV-1965 (UMMZ 220167, figured specimens; UMMZ 220166).

**Habitat.** See p. 162 and Pl. 11, Fig. 7.

**Etymology.** The species is named for Laguna Churince, the type locality.

*Mexipyrus escobedae* TAYLOR, spec. nov.

(Plate 14, Figures 23-26)

**Diagnosis.** One of the smaller species of *Mexipyrus*, attaining a length of 4.5 mm with  $5\frac{1}{2}$  whorls. A peripheral carina develops on the second whorl and begins to weaken on the third whorl. Axial ribs developing on the second whorl increase progressively in strength and dominate other sculpture on the body whorl. They cross the peripheral carina to form nodes on the second and third whorls, and bear nodes on the periphery of the body whorl even when the peripheral cord is not present. A subsutural welt develops on the penultimate whorl, and becomes wider than the peripheral cord. On the body whorl the prosoclyt collabral ribs are the dominant sculpture. They are noded along the periphery and on the subsutural welt even when these spiral cords are not continuous. Fine spiral threads are variably developed. The periostracum has 20 - 30 dark brown bands variably fused and mostly indistinct, but the color of the periostracum is darkest on the subsutural welt and along the periphery, or continuously between both. The ground-color of the periostracum is dark, but bands and ground-color are not always distinct.

**Type.** UMMZ 220202. Coahuila, México: Laguna Escobeda, 12 km south of Cuatro Ciénegas. D. W. Taylor, 15-IV-1965. Others from the same collection are UMMZ 220203 (figured specimen), 220204 (collected alive), and 220205 (empty shells). The species is known only from this laguna (Text figure 2, locality 7). A previous collection by W. L. Minckley, 31-XII-1964, is UMMZ 220208.

**Comparison.** The dominance of axial ribs on the body whorl distinguishes *M. escobedae* from the other species of the genus. In its heavy pigmentation and strong ribs it is like *M. carranzae* of Laguna Tío Candido, but differs conspicuously by smaller size and much weaker spiral sculpture.

**Habitat.** See p. 163.

**Pigmentation.** A series of *Mexipyrus escobedae* survived transport to the laboratory and lived long enough to permit observations on pigmentation and morphology. The features of anatomy that have been studied are mostly included within the description of the genus.

The testis is usually visible as a pale yellow mass within the spire, and thus provides a convenient means for sex

determination. On breaking the shell away from a living snail, one finds the testis is more orange than yellow. This color contrasts with that of the testis in *Mexipyrus caranzae*, which is brilliant red-orange.

When a live snail is withdrawn into its shell the melanin-rich area beneath the operculum appears as a black, roughly semicircular area nearly filling the aperture. The white hyaline granules surrounding the black area are conspicuous in contrast, forming a marginal ring. These features and the attachment of the operculum are readily visible through the thin, nearly colorless operculum. The shell is pale and translucent, so that the black, subopercular area stands in marked contrast to the generally colorless shell and body within.

Extended out of the shell, the snail can be seen to be pale and virtually colorless except for an area of dense melanin pigment in the posterior part of the foot beneath the operculum. This melanin-rich area fades out ventrally toward the sole, and towards the edge of the foot; rarely melanin occurs as a few scattered granules in the anterior  $\frac{1}{5}$  of the foot. Elsewhere in the externally visible body melanin occurs regularly only in a short cylindrical mass in the terminal bulb of the verge, and within the mantle edge. It may occur also in the area behind the tentacles in the back of the head as a diffuse scattering of relatively large granules.

Hyaline bodies appear as relatively large, white or translucent granules densely scattered in the edges of the foot, operculigerous lobe, sides of the body stalk, post-tentacular region, and mantle edge. Smaller, white-appearing granules lie in the skin of the snout and provide the only color there except for the buccal mass. They are sparse or absent in a narrow strip along the mid-dorsal length of the snout, so that the buccal mass, salivary glands, and associated musculature can be seen clearly within. These granules are sparsely scattered in the tentacles, but there are no eye-brow-like masses.

**Etymology.** The species is named for Laguna Escobeda, to which it is restricted.

*Mexipyrus lugoi* TAYLOR, spec. nov.

(Plate 17, Figures 42-45)

**Diagnosis.** One of the larger species of *Mexipyrus*, attaining a length of 7.3 mm with 6 whorls. A peripheral carina develops on the second whorl and is the dominant spiral element on the third to fourth whorls; it may persist on the body whorl as an indistinct cord or fade before then. A subsutural cord develops on the penultimate whorl and may strengthen into a welt. Axial ribs developing on the second whorl cross the peripheral carina to form nodes on the second to fourth whorls, but become weaker toward the body whorl. On the body whorl there may be a subsutural welt and a peripheral cord, or spiral sculpture may consist only of a subsutural swelling that is ill-defined. Axial ribs may persist, or be lacking; when present they are usually little more than low nodes on the periphery and subsutural cord. The periostracum has 25 - 35 narrow dark brown bands of roughly equal width separated by roughly equal interspaces. On the subsutural swelling bands may be wider or closer together. The ground-color of the periostracum varies from nearly colorless to light brown, so that the bands vary in contrast.

**Type.** UMMZ 220185. Coahuila, México: Río Mesquites at the main road 9 km southwest of Cuatro Ciénegas. D. W. Taylor, 13-IV-1965. Others from the same collection are UMMZ 220186 (figured specimens) and 220187. The species is known only from this locality (Text figure 2, Locality 11).

**Comparison.** *Mexipyrus lugoi* is most similar to *M. churinceanus*. It differs in having a more broadly conical shape, with a broader body whorl and larger aperture; and more numerous and narrower brown bands, with no wide band on the subsutural welt.

**Habitat.** See p. 164 and Pl. 11, Fig. 8.

**Etymology.** The species is named in honor of Sr. José Lugo, Jr. of Cuatro Ciénegas, who has aided the study of mollusks and other parts of the remarkable fauna of the

### Explanation of Plate 16

*Mexipyrus churinceanus* TAYLOR, spec. nov., from Río Churince in the Valley of Cuatro Ciénegas, Coahuila.

Photographed by K. Sakamoto.

Figures 33, 34: Type, female, UMMZ 220150. Length 6.2 mm, width 3.1 mm,  $6\frac{3}{4}$  whorls.

Figures 35, 39: Figured specimen, female, UMMZ 220151. Length 6.1 mm, width 3.3 mm,  $6\frac{3}{4}$  whorls.

Figure 36: Figured specimen, male, UMMZ 220151. Length 5.7 mm, width 2.7 mm,  $6\frac{1}{2}$  whorls.

Figures 37, 38: Figured specimen, male, UMMZ 220151. Length 5.3 mm, width 2.6 mm,  $6\frac{3}{4}$  whorls.



Figure 33

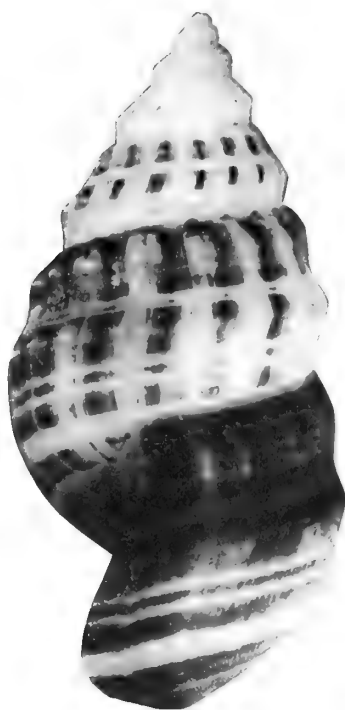


Figure 34

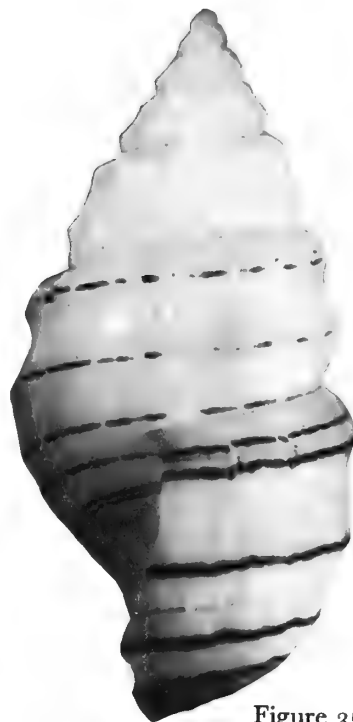


Figure 35



Figure 36



Figure 37

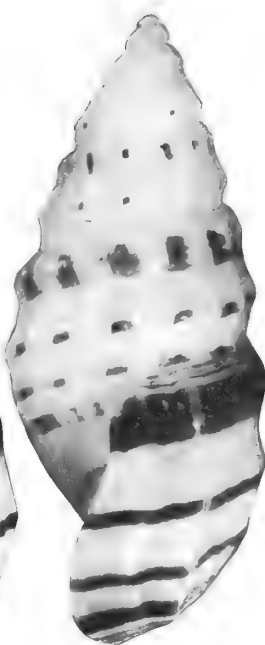


Figure 38



Figure 39



area by providing field assistance, local facilities, and information about the complex drainage of the area.

*Mexipyrus mojarralis* TAYLOR, spec. nov.

(Plate 18, Figures 46-49, 51-53)

**Diagnosis.** One of the smaller species of *Mexipyrus*, attaining a length of 4.5 - 5.0 mm with  $5\frac{1}{2}$  - 6 whorls. A peripheral carina develops on the second whorl and persists as such on the third whorl. Axial ribs developing on the second whorl cross the peripheral carina to form nodes on the second and third whorls but do not persist after the third or fourth whorl. A subsutural welt develops on the penultimate whorl and becomes a round-topped cord higher and wider on the body whorl than the peripheral cord. On the body whorl the only axial sculpture is growth lines; spiral sculpture consists of the subsutural and peripheral cords, always present, and of variably developed fine spiral threads. The periostracum has 2 - 4 brown bands, each on a cord. The color band on the subsutural cord is always present; and it is often wider than the others. The ground color of the periostracum is pale yellowish-brown, so that fresh shells are noticeably darker than empty specimens, even aside from the bands.

**Type.** UMMZ 220192. Coahuila, México: West Laguna in El Mojarral, 1.7 km east-northeast of the northern tip of Sierra de San Marcos. D. W. Taylor, 13-IV-1965. Others from the same collection are UMMZ 220193 (figured specimens) and 220194. The species is known only from this laguna (Text figure 2, locality 5).

**Comparison.** In shape, sculpture, and color of periostracum *Mexipyrus mojarralis* is similar to *M. churinceanus*, on the other side of Sierra de San Marcos. It shares also with that species the frequent occurrence of a broad color band on the subsutural cord 4 - 5 times as wide as most other bands. *Mexipyrus mojarralis* differs in its smaller size, in the constantly fewer bands of color, in the more sharply defined cords on the body whorl, and in the lack of ribs or rugae on the body whorl.

*Mexipyrus mojarralis* is found only about 0.3 km from *M. multilineatus*, and one would expect to find them closely similar. Yet they are not as similar to each other as *M. mojarralis* is to *M. churinceanus*. *Mexipyrus mojarralis* is similar to *M. multilineatus* in its relatively small size, and in the lack of ribs or rugae on the last whorls. They also appear at first sight to be similar in having only a few spiral color bands, but this is an artifact of the wear of the shell. *Mexipyrus multilineatus* differs in its paler periostracum, smoother last whorl, numerous narrow color bands, constant absence of a broad subsutural color band, and narrower aperture and shell form.

**Habitat.** See p. 163 and Plates 9 and 10.

**Etymology.** The species is named for the area of lagunas and marshes called locally El Mojarral. The name is derived from *mojarra*, the name for the cichlid fishes (*Cichlasoma*) that are common in the lagunas there.

*Mexipyrus multilineatus*, TAYLOR, spec. nov.

(Plate 18, Figures 50, 54-57)

**Diagnosis.** One of the smaller species of *Mexipyrus*, attaining a length of 5.0 - 5.1 mm with 6 whorls. A peripheral carina develops on the second whorl and weakens on the penultimate whorl. Axial ribs developing on the second whorl cross the peripheral carina to form nodes on the second and third whorls but do not persist after the third or fourth whorl. A subsutural welt develops on the penultimate whorl and becomes the dominant element of sculpture on the body whorl. On the body whorl the only axial sculpture is growth lines; spiral sculpture consists of a poorly defined subsutural cord, always present, an even more poorly defined, weaker peripheral cord usually present, and variably developed fine spiral threads. The periostracum has 0 - 7 (commonly 2 - 4) narrow brown bands at the beginning of the body whorl; up to about 20 intercalated still narrower bands are often present on the outer lip. The periostracum lacks ground color, so that fresh shells are distinguishable by retaining bands or by a polished surface. The verge has only one accessory process on the left side, unlike other species of the genus. **Type.** UMMZ 220197. Coahuila, México: East Laguna in El Mojarral, 1.9 km east-northeast of the northern tip of Sierra de San Marcos, D. W. Taylor, 13-IV-1965.

Others from the same collection are UMMZ 220198 (figured specimens) and 220199. The species is known only from this laguna (Text figure 2, locality 6).

**Comparison.** *Mexipyrus multilineatus* is found only about 0.3 km from *M. mojarralis*, but has only a few features like that species (q.v.).

Like *Mexipyrus mojarralis*, *M. multilineatus* shows similarities to *M. churinceanus*, found on the other side of Sierra de San Marcos. As a whole, *M. churinceanus* differs in having a darker periostracum, variably wider brown bands, a frequent broad brown band on the subsutural cord, sometimes axial ribs persistent on the body whorl, and longer shell. Specimens of *M. churinceanus* can be selected that are especially close to *M. multilineatus* in shape, sculpture, and in the occurrence of numerous fine brown bands between the broader ones. These specimens differ in having wider bands, darker periostracum, more numerous broad bands and longer shells.

**Habitat.** See p. 163.

**Etymology.** The word *multilineatus* is Latin for many-lined, in reference to a distinctive character of this form.

*Pyrgophorus* ANCEY, 1888

Bull. Soc. Malac. France 5: 188. Type (S. D.: PILSBRY, 1911): *Pyrgophorus spinosus* (CALL & PILSBRY).

The establishment of this group by Ancey reflected keen insight. The characters he used, the scope of the group, and its relationships seem to have been correctly appraised even in the light of the greater knowledge of today.

The shell is spinose to smooth. When spinose, the spines are calcareous blunt projections from the shoulder of the shell. Smooth shells have shallower sutures, and usually have a more broadly conical form and larger aperture than in smooth *Tryonia*. The strong plicate, cancellate, or lirate sculpture of many forms of *Tryonia* is unknown in *Pyrgophorus*.

Previous reviews of species of *Pyrgophorus* have been published by FISCHER (1860) and ANCEY (1888). The following list is intended to be complete.

*Paludina anthracina* MIGHELS, 1845. Proc. Boston Soc. Nat. Hist. 2: 22. Tortola. Assigned to *Pyrgophorus coronatus* by MARTENS (1899).

*Pyrgophorus coronatus ariomus* (CLENCH & AGUAYO, 1937) (*Potamopyrgus*). Mem. Soc. Cubana Hist. Nat. 11: 68, pl. 7, fig. 10. Lake Miragoane, Haiti.

*Pyrgophorus coronatus? bermudezi* (AGUAYO, 1947) (*Lyrodes*). Rev. Soc. Malac. "Carlos de la Torre" 5: 81, fig. 1-3. Pleistocene, near Lago Enriquillo, República Dominicana.

*Pyrgophorus spinosus brevispira* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 193. Comal Creek, New Braunfels, Comal County, Texas, U.S.A.

*Pyrgophorus candeanus* (D'ORBIGNY, 1845) (*Paludetrina*). Sagra, Histoire . . . de l'île de Cuba, Mollusques, 2: 9, pl. 10, figs. 13-14. River Madame, Guadeloupe. Assigned to *P. coronatus* by MARTENS (1899).

*Pyrgophorus chagresensis* (MORRISON, 1946) (*Lyrodes*). Smithson. Misc. Coll. 106 (6): 16, pl. 2, fig. 6, pl. 3,

fig. 6. Chagres River near Gatuncilla, Panamá.

*Pyrgophorus cisternicolus* (MORELET, 1851) (*Paludina*). Testacea novissima 2: 21. Campeche, State of Campeche, México. Assigned to *P. coronatus* by MARTENS (1899).

*Pyrgophorus cisterninus* (KÜSTER, 1852) (*Paludina*). Martini and Chemnitz, Syst. Conch.-Cab. 1 (21): 51, pl. 10, figs. 9-10. Bay of Campeche, México; collected by Arthur Morelet.

*Pyrgophorus conoideus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 196. Nicaragua.

*Pyrgophorus coronatus* (PFEIFFER, 1840) (*Paludina*). Arch. Naturgesch. 6 (1): 253. Matanzas, Prov. Matanzas, Cuba is the type locality according to AGUAYO & JAUME (1947).

*Pyrgophorus coronatus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 197. Vera Cruz, México. Not of PFEIFFER, 1840.

*Pyrgophorus nicaraguanus costuliferus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 195. Nicaragua.

*Pyrgophorus crystallinus* (PFEIFFER, 1840) (*Paludina*). Arch. Naturgesch. 6 (1): 253. Matanzas, Prov. Matanzas, Cuba, is the type locality according to AGUAYO & JAUME (1947). Assigned to *P. coronatus* by MARTENS (1899).

*Pyrgophorus nicaraguanus duplicatus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 195. Nicaragua.

*Pyrgophorus candeanus gibbosus* (FISCHER, 1860) (*Amnicola*). Jour. Conchyl. 8: 364. Formal name for *Paludina coronata* PFEIFFER, "Var. A" of KÜSTER (1852). Bay of Campeche, México; collected by Arthur Morelet. = *Pyrgophorus cisterninus* (KÜSTER).

*Pyrgophorus hibbardi* (LEONARD & FRANZEN, 1944) (*Calipyrgula*). Kansas Univ. Sci. Bull. 30: 19, pl. 4, fig. 7. Lower Pliocene, Laverne Formation, Beaver County, Oklahoma, U.S.A.

*Pyrgophorus hydrobioides* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 201. Lake Coatepeque, Salvador. Ranked as a distinct species by MARTENS (1899).

## Explanation of Plate 17

*Mexipyrgus* from the Valley of Cuatro Ciénegas, Coahuila.

Photographed by K. Sakamoto.

Figure 40, 41: *Mexipyrgus churinceanus* TAYLOR, spec. nov. from Pozos de la Becerra

40: Figured specimen, male, UMMZ 220167. Length 5.1 mm, width 2.7 mm, 5 $\frac{3}{4}$  whorls.

41: Figured specimen, female, UMMZ 220167. Length 6.1 mm, width 3.6 mm, 6 whorls.

Figures 42 to 45: *Mexipyrgus lugoi* TAYLOR, spec. nov. from Río Mesquites.

42. Figured specimen, female, UMMZ 220186. Length 5.7 mm, width 3.5 mm, 5 $\frac{3}{4}$  whorls.

43. Figured specimen, male, UMMZ 220186. Length 7.8 mm, width 3.8 mm, 7 whorls.

44. Figured specimen, male, UMMZ 220186. Length 5.7 mm, width 3.1 mm, 6 $\frac{1}{2}$  whorls.

45. Type, female, UMMZ 220185. Length 6.8 mm, width 3.9 mm, 6 $\frac{1}{2}$  whorls.



Figure 40



Figure 41

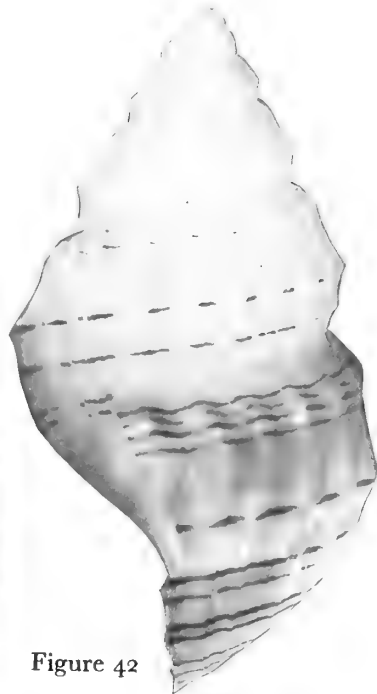


Figure 42



Figure 43

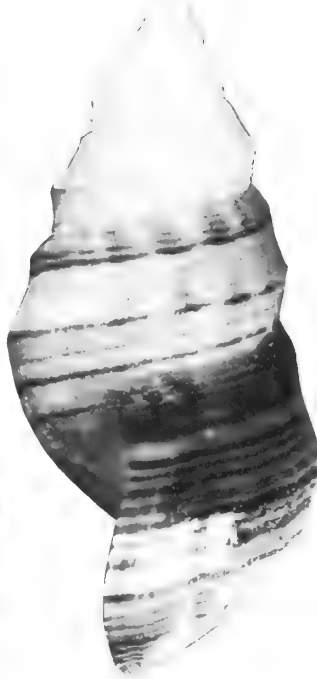


Figure 44

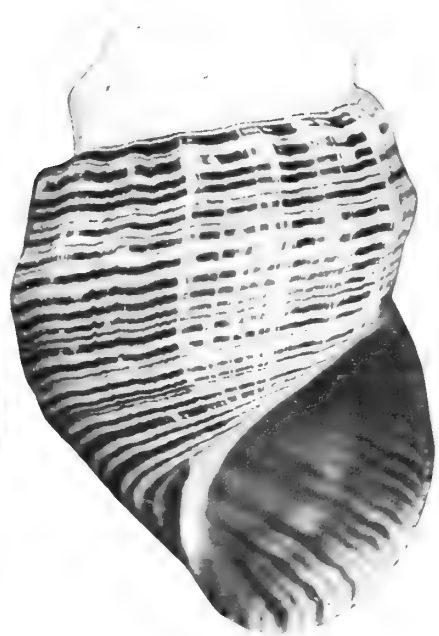


Figure 45





*Pyrgophorus candeanus inermis* (FISCHER, 1860) (*Amnicola*). Jour. Conchyl. 8: 364. No type locality specified; practically nomen nudum. Assigned to *Pyrgophorus coronatus* by MARTENS (1899).

*Paludina jamaicensis* ADAMS, 1849. Contr. Conch.: 42. Jamaica. Assigned to *Pyrgophorus parvulus* by BAKER (1924).

*Pyrgophorus wrighti minimus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 201. Lake Coatepeque, Salvador.

*Pyrgophorus newcombianus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 196. Nicaragua.

*Pyrgophorus nicaraguanus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 194. Nicaragua. Assigned to *P. coronatus* by MARTENS (1899).

*Pyrgula nicaraguensis* NEWCOMB, Ms. Cited by ANCEY (1888) in synonymy of *Pyrgophorus nicaraguanus*. Nomen nudum.

*Pyrgophorus wrighti obesus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 201. Lake Coatepeque, Salvador.

*Pyrgophorus wrighti oblongus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 200. Lake Coatepeque, Salvador.

*Pyrgophorus ornatus* (MORELET, 1851) (*Paludina*). Testacea novissima 2: 21. Laguna Coatepeque, Salvador. Assigned to *Pyrgophorus coronatus* by MARTENS (1899).

*Pyrgophorus parvulus* (GUILDING, 1828) (*Paludina*). Zool. Jour. 3: 537, suppl. pl. 28, fig. 1-3. St. Vincent, Windward Islands, British West Indies. According to BAKER (1924, 1930) the species ranges through Jamaica, Haiti, St. Thomas, St. Vincent, Grenada, Curaçao, Aruba, Bonaire, Klein-Bonaire, and in the Río Yumarito, near Boquerón, State of Yaracuy, Venezuela.

*Pyrgophorus wrighti plicatus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 199. Lake Coatepeque, Salvador.

*Pyrgophorus productus* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 197. Nicaragua.

*Pyrgophorus reevii* (FRAUENFELD, 1863) (*Hydrobia*). Verhandl. k.k. zoolog.-bot. Gesellsch. Wien 13: 1024; 15: 526, pl. 8.

*Calipyrgula senta* LEONARD & FRANZEN, 1944. Kansas Univ. Sci. Bull. 30: 21, pl. 4, fig. 8. Lower Pliocene, Laverne Formation, Beaver County, Oklahoma. = *Pyrgophorus hibbardi*.

*Pyrgophorus spiniferus* (ADAMS, 1845) (*Melania*). Proc. Boston Soc. Nat. Hist. 2: 17. Jamaica. Assigned to *P. coronatus* by MARTENS (1899).

*Pyrgophorus spinosus* (CALL & PILSBRY, 1886) (*Pyrgulopsis*). Proc. Davenport Acad. Nat. Sci. 5: 14, pl. 2, figs.

17-19. Comal Creek, New Braunfels, Comal County, Texas, U.S.A. Assigned to *Pyrgophorus coronatus* by MARTENS (1899).

*Bithinia spiralis* GUPPY, 1864. Ann. Mag. Nat. Hist., ser. 3, 14: 244. Trinidad. Assigned to *Pyrgophorus parvulus* by BAKER (1930).

*Hydrobia texana* PILSBRY, 1887. Proc. Davenport Acad. Nat. Sci. 5: 33, pl. 3, figs. 1-6. Guadalupe River and Comal Creek, Comal County, Texas, U.S.A. Referred by PILSBRY (1891) to *Pyrgophorus spinosus*.

*Pyrgophorus wrighti transitans* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 200. Lake Coatepeque, Salvador.

*Calipyrgula tumida* LEONARD & FRANZEN, 1944. Kansas Univ. Sci. Bull. 30: 20, pl. 4, fig. 9. Lower Pliocene, Laverne Formation, Beaver County, Oklahoma, U.S.A. = *Pyrgophorus hibbardi*.

*Calipyrgula turricula* LEONARD & FRANZEN, 1944. Kansas Univ. Sci. Bull. 30: 20, pl. 4, fig. 4. Lower Pliocene, Laverne Formation, Beaver County, Oklahoma, U.S.A. = *Pyrgophorus hibbardi*.

*Pyrgophorus coronatus uncarinatus* (VON MARTENS, 1899) (*Amnicola*). Biol. Centr.-Amer., Moll.: 433. Nomen nudum. Reported from Cuba by AGUAYO & JAUME (1947).

*Pyrgophorus valenciae* (PRESTON, 1909) (*Paludestri-na*). Ann. Mag. Nat. Hist., ser. 8, 3: 513, pl. 10, fig. 16. Lago de Valencia, Venezuela. Ranked as a distinct species by BAKER (1930).

*Pyrgophorus wrighti* (ANCEY, 1888) (*Pyrgulopsis*). Bull. Soc. Malac. France 5: 199. Lake Coatepeque, Salvador. Assigned to *Pyrgophorus coronatus* by MARTENS (1899).

*Pyrgophorus zeteki* (MORRISON, 1946) (*Lyrodes*). Smithsonian. Misc. Coll. 106 (6): 17, pl. 2, fig. 10. Pedro Miguel, Panama Canal Zone.

#### Spurious species of *Pyrgophorus*

A number of species have been described by previous authors under the names *Potamopyrgus*, *Pyrgulopsis* or *Lyrodes* and were evidently thought to belong to the group here called *Pyrgophorus*. Virtually all of the spurious forms are assigned herein to *Aroapyrgus* (Hydrobiinae), or to some genus of Littoridininae, and have been listed under the appropriate category. One species seems to me unlikely to belong even in the Littoridininae: *Lyrodes hertleini* DRAKE (1956), from springs at Las Palomas, Chihuahua, México. If it belongs to an already described group then it might belong to *Fontelicella* GREGG & TAYLOR (1965), but so little is known of Hydrobiidae in the region that one can only speculate.

*Rhampophoma* HAAS, 1955

Trans. Linn. Soc. London, ser. 3, 1: 298. Type (O.D.): *Rhampophoma magnum* HAAS.

The shell is turritiform, as in *Littoridina*. The operculum is ovate in plan along the outer margin, but produced toward the nucleus so that a hollow narrow tube with slight spiral twist projects toward the baso-columellar margin.

*Rhampophoma magnum* HAAS, 1955. Trans. Linn. Soc. London, ser. 3, 1: 299, text-fig. 24. Lake Titicaca, Peru.

*Rhampophoma parvum* HAAS, 1955. Trans. Linn. Soc. London, ser. 3, 1: 300, text-fig. 25. Lake Titicaca, Peru.

*Strombopoma* HAAS, 1955

Trans. Linn. Soc. London, ser. 3, 1: 296. Type (O.D.): *Strombopoma orton* (PILSBRY).

The shell is turritiform, as in *Littoridina*. The operculum is multispiral, with as many whorls as the shell, conical and hollow, with the edge of each whorl projecting to form a spiral lamella around the outer surface of the cone.

*Strombopoma gracile* HAAS, 1955. Trans. Linn. Soc. London, ser. 3, 1: 298, text-fig. 23. Lagunilla Lagunilla, basin of Lake Titicaca, Peru.

*Strombopoma orton* (PILSBRY, 1924) (*Littoridina*). Proc. Acad. Nat. Sci. Philadelphia 76: 53, text-fig. 1d. Found only in Lake Titicaca, Peru (HAAS, 1955).

*Strombopoma titicacae* "HAAS," HUBENDICK, 1955. Trans. Linn. Soc. London, ser. 3, 1: 323, 325, text-figs. 81-82, 90. Nomen nudum. = *S. orton* (PILSBRY).

*Texadina* ABBOTT & LADD, 1951

Jour. Wash. Acad. Sci. 41: 335. Type (O.D.): *Littoridina sphinctostoma* ABBOTT & LADD.

The peristome is constricted, and the last third of the body whorl descends more rapidly than in typical *Littoridina*. Other than the radula, operculum, and general shape of the head, the anatomy is unknown. *Texadina* may perhaps prove to be a senior synonym of *Littoridinops* when other details of its anatomy are known.

*Texadina sphinctostoma* (ABBOTT & LADD), 1951 (*Littoridina*). Jour. Wash. Acad. Sci. 41: 335, text-figs. 1-12. Brackish waters in the vicinity of Rockport and Aransas Pass, Texas, and Grand Isle, Louisiana, U.S.A. Subsequently reported from other Louisiana localities by SOLEM (1961) and KEITH & PARKER (1965).

*Tryonia* STIMPSON, 1865

*Tryonia* STIMPSON, 1865. Amer. Jour. Conch. 1: 54. Type (O.D.): *T. clathrata* STIMPSON.

*Isaea* CONRAD, 1871. Amer. Jour. Conch. 6: 193. Type (here designated): *Mesalia orton* GABB, 1869. Not of EDWARDS, 1830.

*Liris* CONRAD, 1871. Amer. Jour. Conch. 6: 193. Type (M.): *Liris laqueata* CONRAD.

*Dyris* CONRAD, 1871. Amer. Jour. Conch. 6: 195. Type (M.): *Dyris gracilis* CONRAD.

*Conradia* WENZ, 1925. Senckenbergiana 7: 125. New name for *Isaea* CONRAD, not EDWARDS. Not of A. ADAMS, 1860.

Shell turritiform, with more whorls, a narrower outline, smaller aperture, and deeper suture than in most *Pyrgophorus*. The sculpture may consist only of growth line, or may be coarsely lirate, plicate, or reticulate. Spines on the shoulder of the shell (characteristic of *Pyrgophorus*) are unknown in *Tryonia*.

Virtually all of the species are known by shell alone, so that no trenchant characterization of the genus is possible. *Tryonia cheatumi* is known to be ovoviviparous like *Pyrgophorus* (PILSBRY, 1935b).

Most of the range of *Tryonia* is within the high plateaus of southwestern North and Central America that now have internal drainage (Great Basin in western U.S.A.; Laguna Petén-Itza, Dept. Petén, Guatemala) or that drain to the Pacific Ocean. The only occurrences in Atlantic drainage are those in the Pecos River valley (tributary to Rio Grande), New Mexico and Texas, U.S.A.; a Tertiary occurrence on Río Carboneras, tributary to Lake Izabal, Guatemala, and so to the Caribbean (DALL, 1924a, b); and the South American records. Nearly all of these localities are in regions where there are, or were in late Tertiary times, extensive lake basins.

*Tryonia amazonica* (HAAS, 1949) (*Potamopyrgus*). An. Inst. Biol. Mex. 20: 313; text-fig. 6. Río Tapajóz, Balterra, Pará, Brasil.

*Tryonia bakeri* (PILSBRY, 1891) (*Potamopyrgus*?). Nautilus 5: 9. Proc. Acad. Nat. Sci. Philadelphia 43: 328, pl. 15, figs. 9-11. Subfossil, streambank east of Yautepec, Morelos, México.

*Tryonia bicarinata* (ETHERIDGE, 1879) (*Melania*). Quart. Jour. Geol. Soc. London 35: 88, pl. 7, fig. 7. Pliocene?, Canama, Prov. Loreto, Perú. Referred by WENZ (1926) to *T. tricarinata*, but DE GREVE (1938) doubted such an assignment.

*Pyrgulopsis blakeana* TAYLOR, 1950. Leaf. Malac. 1: 30, text-figs. 4-6. Subfossil, Fish Springs, Imperial County, California, U.S.A. = *Tryonia protea* (GOULD).

*Pyrgulopsis cahuillarum* TAYLOR, 1950. Leaf. Malac. 1: 31, text-fig. 7. Subfossil, 7.9 miles west of Mecca, Colorado Desert, California, U.S.A. = *Tryonia protea* (GOULD).

*Tryonia cheatumi* (PILSBRY, 1935) (*Potamopyrgus*). Nautilus 48: 91, text-fig. 4. Phantom Lake, near Toyahvale, Reeves County, Texas, U.S.A.

*Tryonia circumstriata* (LEONARD & Ho, 1960b) (*Calipyrgula*). Nautilus 73: 125, pl. 12, figs. 1-3. Late Pleistocene terrace deposits along Pecos River ¼ mile above

mouth of Independence Creek, on Chandler Ranch, Terrell County, Texas. Also known from 2 other localities as a fossil in Terrell and Pecos Counties, Texas, U.S.A.

*Tryonia clathrata* STIMPSON, 1865. Amer. Jour. Conch. 1: 54; pl. 8, fig. 1. The type locality was given as the Colorado Desert, California. In the light of present knowledge most likely the original subfossil material came from near the lower course of the Muddy River, Clark County, Nevada, U.S.A. The species lives only in the Pahrnagat Valley, southern Nevada.

*Tryonia confusa* (BOETTGER, 1878) (*Hydrobia*). Jahrb. k.-k. geol. Reichsanst. 28: 491, pl. 13, figs. 4a, b, 6a, b, 7a-c. Pliocene?, Pebas, Prov. Loreto, Perú. Reported also from Iquitos, Prov. Loreto, by DE GREVE (1938).

*Paludestrina curta* ARNOLD, 1903. Mem. Calif. Acad. Sci. 3: 305, pl. 8, fig. 2. Pleistocene, San Pedro Sand and Palos Verdes Sand, San Pedro, Los Angeles Co., California. = *Tryonia imitator* (PILSBRY) according to TAYLOR (1966a).

*Tryonia exigua* (MORELET, 1851) (*Melania*). Testacea novissima 2: 23. Laguna Petén-Itza, Dept. Petén, Guatemala.

*Melania exigua* CONRAD, 1855. Proc. Acad. Nat. Sci. Philadelphia 7: 269. Colorado Desert, California, U.S.A. (subfossil). = *Tryonia protea* (GOULD). Preoccupied by *Melania exigua* MORELET, 1851, also a *Tryonia*.

*Tryonia jagundesii* (HAAS, 1938) (*Potamopyrgus*). Arch. Molluskenk. 70: 50, text-figs. 8-9. Recife, Pernambuco, Brasil. Recorded from the same area by HAAS (1939).

*Tryonia gracilis* (CONRAD, 1871) (*Dyrus*). Amer. Jour. Conch. 6: 195, pl. 10, fig. 8; pl. 11, fig. 7. Pliocene? Pichua, below Pebas, Prov. Loreto, Peru. Reported also from Canama, Pebas, and Iquitos, all Prov. Loreto, Peru (BOETTGER, 1878; ETHERIDGE, 1879; DE GREVE, 1938).

*Tryonia imitator* (PILSBRY, 1899) (*Paludestrina*). Nautilus 12: 124. Santa Cruz, Santa Cruz Co., California. Published and unpublished records indicate a range from San Francisco Bay to San Diego County, California, in brackish water, and a geologic range as far back as the late Miocene or early Pliocene (OAKESHOTT, 1958).

*Alabina io* BARTSCH, 1911. Proc. U.S. Nat. Mus. 39: 415, pl. 61, fig. 1. Originally stated to be from Pleistocene deposits at San Diego, San Diego County, California, but according to WOODRING *et al.* (1946:67) it is from San Pedro, Los Angeles County, California, U.S.A. The stratigraphic horizon of the type is unknown; it might be upper or lower Pleistocene. = *Tryonia stokesi* (ARNOLD) according to TAYLOR (1966a).

*Tryonia lacirana* (PILSBRY & OLSSON, 1935) (*Potamopyrgus*). Proc. Acad. Nat. Sci. Philadelphia 87: 9, pl. 5,

fig. 6. Upper Oligocene or lower Miocene, La Cira Formation, La Cira district, Prov. Santander, Colombia.

*Tryonia laqueata* (CONRAD, 1871) (*Liris*). Amer. Jour. Conch. 6: 194, pl. 10, fig. 3. Pliocene?, Pichua, below Pebas, Prov. Loreto, Peru. Reported also from Iquitos, Prov. Loreto, Peru (DE GREVE, 1938).

*Tryonia lintea* (CONRAD, 1871) (*Isaea*). Amer. Jour. Conch. 6: 193, pl. 10, fig. 6. Pliocene? Pichua, below Pebas, Prov. Loreto, Peru. Reported also from Iquitos, Prov. Loreto, Peru (DE GREVE, 1938).

*Tryonia minuscula* (GABB, 1869) (*Turbonilla*). Amer. Jour. Conch. 4: 197, pl. 16, fig. 1. Pliocene?, Pebas, Prov. Loreto, Peru. Reported also from Canama, Tres Unidos, and Iquitos, Prov. Loreto, Peru; and Rio Quixito and Cachoeira das Fracoas, Amazonas, Brasil (ETHERIDGE, 1879; ROXO, 1924; DE GREVE, 1938).

*Melania minuta* BROU, 1862. Matériaux . . . Catalogue systématique . . . des Mélaniens: 43. New name for *Melania exigua* (MORELET) as described by REEVE (1861). = *Tryonia exigua* (MORELET) according to FISCHER & CROSSE (1870-1902).

*Tryonia ortonii* (GABB, 1869) (*Mesalia*). Amer. Jour. Conch. 4: 198, pl. 16, fig. 3. Pliocene?, Pebas, Prov. Loreto, Perú. Reported also from Pichua and Iquitos, Prov. Loreto, Peru (CONRAD, 1871; DE GREVE, 1938).

*Tryonia patzcuarensis* (PILSBRY, 1891) (*Pyrgulopsis?*). Nautilus 5: 9. Proc. Acad. Nat. Sci. Philadelphia 43: 330, pl. 15, fig. 8. Lake Patzcuaro, Michoacán, México.

*Tryonia pecosensis* (LEONARD & HO, 1960a) (*Calipygula*). Nautilus 73: 110, pl. 11, fig. 1-3. Late Pleistocene terrace deposits along Pecos River, 3.5 miles northeast of Imperial, Crane County, Texas. Also known from 5 other localities as a fossil in Pecos and Ward Counties, Texas, U.S.A.

*Tryonia protea* (GOULD, 1855) (*Amnicola*). Proc. Boston Soc. Nat. Hist. 5: 129. Subfossil, Colorado Desert, California, U.S.A.

*Tryonia scalarioides* (ETHERIDGE, 1879) (*Melania*). Quart. Jour. Geol. Soc. London 35: 88, pl. 7, fig. 8. Pliocene? Canama, Prov. Loreto, Peru.

*Tryonia stokesi* (ARNOLD, 1903). Mem. Calif. Acad. Sci. 3: 22, 23, 44, 305, pl. 8, fig. 3 (*Paludestrina*). Lower Pleistocene, San Pedro Sand, San Pedro, Los Angeles County, California, U.S.A.

*Tryonia tricarinata* (BOETTGER, 1871) (*Hydrobia*). Jahrb. k.-k. geol. Reichsanst. 28: 492, pl. 13, figs. 10a, b, 11a-c. Pliocene?, Pebas, Prov. Loreto, Peru. Reported also from Canama and Iquitos, Prov. Loreto, Perú (ETHERIDGE, 1879; DE GREVE, 1938).

*Tryonia tuberculata* (DE GREVE, 1938) (*Liris*). Abh. Schweiz. Paleont. Gesellsch. 61 (3): 96, 125, pl. 2, figs.

32-35; pl. 3, figs. 1-20; text-fig. 19-22. Pliocene? Iquitos, Prov. Loreto, Peru.

#### *Zetekina* MORRISON, 1947

*Zetekella* MORRISON, 1946. *Smithson. Misc. Coll.* 106 (6): 11. Type (O.D.): *Zetekella frenata* (PILSBRY). Not of DRAKE, 1944.

*Zetekina* MORRISON, 1947. *Nautilus* 60: 102. New name for *Zetekella* MORRISON, 1946, not DRAKE, 1944.

The verges of *Zetekina frenata*, *Z. kompi*, and *Z. veraguasensis* have been figured by MORRISON (1946) and PILSBRY (1935b). The modern distribution of the genus is in the Pacific drainage from Nicaragua to central Panamá and the Pearl Islands, Panamá; a Pliocene species is known from California, U.S.A.

*Zetekina frenata* (PILSBRY, 1935) (*Littoridina*). *Proc. Acad. Nat. Sci. Philadelphia* 87: 5, text-figs. 1, 1a. Río Juan Díaz, Panamá.

*Zetekina kompi* (MORRISON, 1946) (*Zetekella*). *Smithson. Misc. Coll.* 106 (6): 13, pl. 2, fig. 2; pl. 3, fig. 2. Río Mata Puerco, San José Island, Archipiélago de las Perlas, Panamá.

*Zetekina martensi* (PILSBRY, 1935) (*Littoridina*). *Proc. Acad. Nat. Sci. Philadelphia* 87: 5, text-fig. 2. Río Fula, Nicaragua. So assigned by MORRISON (1946).

*Zetekina melanioides* (MARTENS, 1899) (*Amnicola?*). *Biol. Centr.-Am., Moll.*: 436, pl. 22, fig. 8. Río de los Platanales, Golfo Dulce, Costa Rica. So assigned by MORRISON (1946).

*Zetekina panamensis* (BARTSCH, 1920) (*Syncera*). *Proc. U.S. Nat. Mus.* 58: 164, pl. 12, fig. 8. Río Matasnillo, Panamá. So assigned by MORRISON (1946).

*Zetekina tenuis* (MARTENS, 1899) (*Amnicola?*). *Biol. Centr.-Amer., Moll.*: 436, pl. 22, fig. 9. Tributary of Río Boto at Golfo Dulce, and marshes of Seripe, Costa Rica. Considered of specific rank by PILSBRY (1935).

*Zetekina veraguasensis* (MORRISON, 1946) (*Zetekella*). *Smithson. Misc. Coll.* 106 (6): 12, pl. 2, fig. 1; pl. 3, fig. 1. Río Tribiqué, Sona, Veraguas Prov., Panamá.

*Zetekina woodringi* (PILSBRY, 1934) (*Littoridina*). *Nautilus* 48: 16. PILSBRY, 1935, *Proc. Acad. Nat. Sci. Philadelphia* 86: 558, pl. 21, fig. 3, 4. Late Pliocene, basal part of Tulare Formation, Kettleman Hills, California, U.S.A. So assigned by TAYLOR (1966a).

The verge is known only by the description and illustrations published by MORRISON (1946) and PILSBRY (1935c). So far as one can interpret them, there is a very short, melanin-pigmented free part of the penis, as in *Mexipyr-gus* and at least some *Tryonia*; and 2 bulbous or elongate accessory processes on the left side near the distal end,

as in *Durangonella*. From these meager data, and from geographic distribution, the genus appears most likely to be one of the Littoridininae. The radula is still unknown.

#### Littoridininae?, incertae sedis

One broken and bleached shell (UMMZ 220178) was found in a bottom sample from the northernmost pool of Pozos de la Becerra, 18 km southwest of Cuatro Ciénegas, Coahuila, México, collected by C. L. Hubbs, 6-IV-1961. The specimen measures 0.6 x 0.5 mm, with 2½ whorls that are nearly circular in cross-section, separated by a deeply incised suture, and retain ornament of growth lines only. The shell is far too narrow and has more whorls for its size than *Mexipyr-gus*. The nearest form is *Durango-nella*, but the species of that genus in the Cuatro Ciénegas valley have whorls that lengthen more rapidly and are more oval in cross-section. This single shell evidently represents a species otherwise unknown in the area, perhaps *Durangonella* or some other genus.

#### Lyogyrinae

Shell trochoid to turritiform, with whorls nearly circular in cross-section, separated by a deeply incised suture; operculum multispiral as in *Valvata*, more tightly coiled than in Cochliopinae.

Referred genera: The one genus included is *Lyogyrus* GILL, 1863, known from the Atlantic and Gulf coasts of the U.S.A., from Massachusetts to Alabama.

WALKER (1918) attributed the name Lyogyrinae to PILSBRY (1916); this reference is a bare mention of the name, and WALKER seems to be the taxonomic author of the group.

#### *Lyogyrus* GILL, 1863

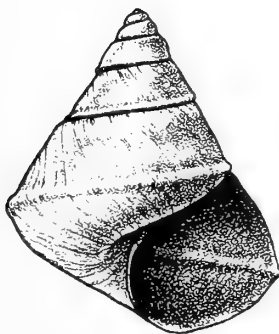
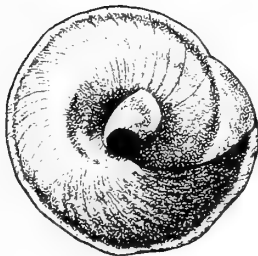
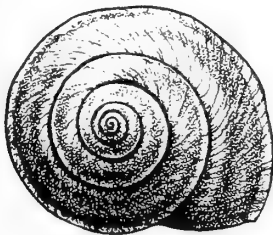
*Proc. Acad. Nat. Sci. Philadelphia* 15: 34. Type (O.D.) *Valvata pupoidea* GOULD. Described as genus of Valvatidae.

Literature on the 5 nominal species is accessible through WALKER (1918) and VANATTA (1934).

Virtually nothing is known of this group. The radula has been briefly mentioned by PILSBRY (1888, 1892) as like that of the Hydrobiidae instead of the Valvatidae, and for this reason the genus has been so classified ever since. If GOULD (1841: 227) correctly described the ctenidium as protrusible, then *Lyogyrus* cannot be one of the Hydrobiidae and might indeed show characters in common with Valvatidae. But from the fact that Gould stated the respiratory organ was protruded on the right, I suspect his observation is based on misidentification of the verge, or perhaps a pallial tentacle on the right side.

**Nymphophilinae** TAYLOR, new subfamily

Shell large for the family, attaining a length of 10 mm, trochoid, narrowly phaneromphalous, with a flat-sided spire and a single persistent spiral carina. Operculum (Text figure 20) multispiral with a central nucleus. Vas deferens in a raised ridge on the floor of the mantle cavity, rather than beneath it. Verge (Text figure 21) with glandular accessory process, and a free part of the penis that is relatively mobile and distensible for the family and contains a noticeable blood sinus. Eggs single in smooth, hemispherical capsules.



Figures 17 to 19

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

Type, UMMZ 220183. Length 7.0 mm; width 6.0 mm;  $5\frac{3}{4}$  whorls.

**Referred genera.** *Nymphophilus* TAYLOR, gen. nov., is the only included genus. The subfamily is thus known only from the valley of Cuatro Ciénegas, Coahuila, México.

Establishing a new subfamily for this unusual genus would not be warranted on shell characters alone, but there are some features unique in the family, and others that are rare. The multispiral operculum is a distinctive character, otherwise known in American Hydrobiidae only in the Cochliopinae and Lyogyrinae. The shell is remarkably large for the family, equaled only in Lithoglyphinae, and most un-hydrobiid in general appearance; it reminds one more of the marine Trochidae. The shape of the verge is not distinctive—it might belong to the Hydrobiinae—but the distensible penis and evident blood sinus are not like any Hydrobiidae I have studied or found in the literature. The course of the vas deferens in a ridge on top of the mantle cavity floor is unique, and seemingly not correlated with other structures.

***Nymphophilus* TAYLOR, gen. nov.**

**Diagnosis.** Same as for the subfamily.

**Type.** *Nymphophilus minckleyi* TAYLOR, spec. nov. No other species are known in the genus.

**Etymology.** The name is from *Nymphaea*, the water-lily; and Greek *philos*, beloved, dear. The genus is characteristically found on *Nymphaea* leaves in the lagunas of the Cuatro Ciénegas region.

***Nymphophilus minckleyi* TAYLOR, spec. nov.**

(Plate 13, Figures 15, 17; Text figures 17-21)

**Diagnosis.** Same as for the subfamily.

**Type.** UMMZ 220188. Coahuila, México: Río Mesquites at the main road 9 km southwest of Cuatro Ciénegas. D. W. Taylor, 13-IV-1965. The same collection yielded a number of other specimens, some of which were destroyed for cytological or morphological study; those preserved are UMMZ 220189. The locality is number 11 on Text figure 2.

**Localities and material examined** (listed in geographic sequence around Sierra de San Marcos, beginning at the southwest).

Laguna Churince, 16 km SW Cuatro Ciénegas; D. W. Taylor, 12-IV-1965 (UMMZ 220154).

Unnamed laguna west of Río Churince; D. W. Taylor, 14-IV-1965 (UMMZ 220156).

Pozos de la Becerra, 14 km SW Cuatro Ciénegas; C. L. Hubbs, 6-IV-1961 (UMMZ 220175); W. L. Minckley,

28-XII-1964 (UMMZ 220172); D. W. Taylor, 14-IV-1965 (UMMZ 220169).

<sup>a</sup>Río Mesquites, 9 km SW Cuatro Ciénegas; D. W. Taylor, 13-IV-1965 (UMMZ 220188, 220189).

West Laguna in El Mojarral, 1.7 km ENE of tip of Sierra de San Marcos; D. W. Taylor, 13-IV-1965 (UMMZ 220196).

East Laguna in El Mojarral, 1.9 km ENE of tip of Sierra de San Marcos; D. W. Taylor, 13-IV-1965 (UMMZ 220201).

<sup>a</sup>Laguna Escobeda, 12 km S of Cuatro Ciénegas; W. L. Minckley, 31-XII-1964 (UMMZ 220210); D. W. Taylor, 15-IV-1965 (UMMZ 220207).

<sup>a</sup>Laguna Tío Candido, 14 km S Cuatro Ciénegas; D. W. Taylor, 15-IV-1965 (UMMZ 220216).

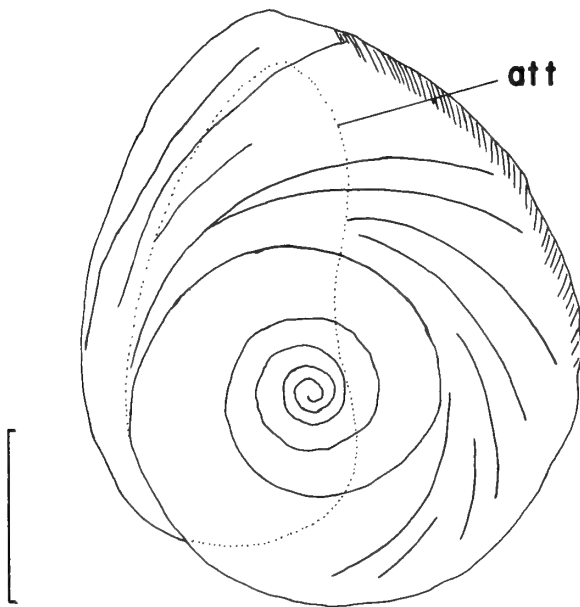


Figure 20

Operculum of *Nymphophilus minckleyi* TAYLOR, gen. et spec. nov., external view;

scale line = 1.0 mm. att - border of attachment to foot.

**General form, locomotion, behavior.** The conical shell about 10 mm long in adults is borne free of the substratum with the apex directed upward and posteriorly to the right, so that the axis of the shell forms an angle of about

45-60 degrees with the long axis of the foot. In dorsal view when the snails are crawling the tip of the snout, most of the length of the tentacles, and the hind end and anterior corners of the foot are visible. The eyes are not usually visible in this view. Compared to other Hydrobiidae seen the snails crawl at moderate speed; they move smoothly and do not show the stepwise gait of the Pomatiopsinae. The animal can right itself only with difficulty when turned on its back.

The tentacles are nearly as long as the aperture, and taper gently to rounded tips. They show no definite arrangement of cilia. The tentacles are borne diverging at an angle of about 90-120 degrees, and usually are in vertical or horizontal movement. They move both above and below a plane parallel to the substratum, and often touch the substratum as if sensing it. In crawling the snail keeps its snout appressed to the substratum, and moves it from side to side while browsing. The movement of the radula can be seen within the translucent snout.

**Pigmentation.** The shell and external body are a similar light ochre color in gross aspect. The shell is translucent, so that some internal structures can be seen through the shell, but the organs contain so little pigment that none of them can be discerned clearly. Elements of color are very fine granules of melanin, mostly occurring as a thin dust in the surface epithelium of the head-foot mass, and larger hyaline granules that are scattered in the tissue and appear pale yellow.

The sole of the foot appears very pale yellow-gray. The central part is clear and translucent, but the sides and hind part contain scattered yellowish hyaline granules and melanin granules that give it a darker hue. The anterior edge is clear like the central area, so that the mucus glands can be seen within the foot. In ventral view the operculigerous lobe appears darker than the borders of the sole, from more abundant melanin and hyaline granules.

The sides and top of the head-foot area are lightly coated with brown-appearing melanin granules. Together with the abundant hyaline granules in the tissue they give the body its ochre color. No definite pattern is evident, except that the melanin and hyaline granules are a little more heavily concentrated behind the eyes.

**Head-foot mass.** The foot is about twice as long as wide, with a constriction behind the anterior corners and a broadly rounded posterior end. The anterior mucous glands are visible through the sole, emptying into the anterior pedal groove. The snout is short and tapers conspicuously. Its width at the base of the tentacles is about equal to its length from the mouth to the tentacles. The outline of the reddish-brown buccal mass can be seen within, and the esophagus extending posteriorly. In cross-section the snout is oval, more convex dorsally. The fleshy pad at the

<sup>a</sup> Population studied from living specimens as well as relaxed, fixed material.

<sup>a</sup> Population extinct.



anterior end is separated from the rest of the snout by a narrow incised groove, and divided in two by the slit of the mouth.

The tentacles are stout and taper regularly to rounded tips. They are circular in cross-section toward the tips, but oval and flattened dorso-ventrally toward the base. Cilia are uniformly distributed on their surface. The eyes lie in prominent discrete swellings on the outer bases of the tentacles.

The operculigerous lobe is indistinct, not separated from the rest of the foot by grooves or special ciliated areas. In ventral view the lobe appears as a couple of buttress-like swellings that run from the dorsal edge of the sole to the anterior-lateral regions of the operculum. The operculum overhangs the operculigerous lobe from the farthest lateral projections of the lobe on around behind.

**Mantle cavity.** The edge of the mantle is thickened to form a collar, but is otherwise smooth. The collar contains abundant hyaline granules and is suffused with fine melanin granules. An observer looking into the cavity of a living snail can see the ctenidium, anus and distal part of the rectum, and verge; the osphradium and end of the female genital system are visible only on close inspection. No grooves lead in or out of the mantle cavity, but a ciliated tract runs out of the mantle cavity down the right side of the head-foot to the edge of the sole. As usual, circulation of water is in on the left and out on the right.

The ctenidium extends farther toward the edge of the mantle cavity than any other structure in it, except for the verge when that is extended. The most distal lamellae in the ctenidium are attached to the mantle next to the collar. The ctenidium as a whole consists of about 40 lamellae, each in the form of an acute triangle hanging from the mantle and pointing toward the floor of the cavity. The ctenidium runs the length of the cavity, dividing it into 2 equal parts; the right margin of the ctenidium lies below the peripheral carina on the shell.

The anus lies about  $\frac{1}{8}$  whorl within the aperture. The rectum is attached to the mantle throughout its course, and lies in the angle of the mantle cavity next to the suture.

**Male reproductive system.** The male reproductive system in *Nymphophilus* consists of the organs common to Hydrobiidae in general. The testis in the upper visceral mass produces sperms which are led through a collecting duct into that part of the upper vas deferens specialized as a seminal vesicle, thence through the upper vas to the prostate, then through the lower vas on the floor of the mantle cavity into the verge. The special features of the animal are the course and size of the lower vas deferens, and the details of shape and structure of the verge.

The testis lies in the posterior  $\frac{1}{2}$  to  $\frac{2}{3}$  of the first and second whorls. It is closely appressed to the very pale gray digestive gland from which it is readily distinguished by its bright yellow color. The testis does not extend to the tip of the visceral mass; the first half whorl and the anterior parts of the next  $1\frac{1}{2}$  whorls are taken up by the digestive gland.

The digitiform follicles making up the testis discharge via the vasa efferentia into a common collecting duct. The duct leaves the columellar aspect of the testis at about midlength. This structure contrasts with that in some other Hydrobiidae, in which the follicles discharge in several groups into a duct leaving the testis at its proximal end.

The pale, narrow, thin-walled common collecting duct enlarges rapidly after its emergence from the testis into a thick-walled, highly convoluted tube 2-3 times its previous diameter. This tube is the part of the upper vas deferens specialized as a seminal vesicle. The lumen is about  $\frac{3}{4}$  the diameter of the tube, and crowded with sperm readily visible as a white mass through the translucent walls of the vesicle. The seminal vesicle lies in the columellar aspect of the visceral mass for about one whorl, extending to the level of the stomach.

The upper vas deferens narrows gradually, and the white mass of sperm inside becomes progressively narrower, until it is again a pale, narrow, thin-walled tube like the collecting duct. Here it leaves the visceral mass proper, and enters a dense mass of connective tissue dorsal to the hind end of the columellar muscle, ventral to the prostate gland, just behind the visceral ganglion and to the right of the hind end of the mantle cavity. It enters the prostate gland at about mid-length on the ventral side.

The prostate gland is a whitish elongate-body of loose texture that lies next to the right hind end of the mantle cavity, but does not project into it. The visceral ganglion lies directly beneath it.

The lower vas deferens emerges from the prostate on the ventral side at nearly midlength, close in front of the entrance of the upper vas into the prostate. The lower vas then runs in the right wall of the mantle cavity, first anteriorly, then ventrally, to the floor of the mantle cavity at about mid-length of that cavity. The lower vas is a tube obviously thicker than the upper vas where it enters the prostate, but only about half as thick as the seminal vesicle, and with less translucent walls. On reaching the floor of the mantle cavity the vas deferens runs as a raised ridge on the floor of the mantle cavity, first to the left until it reaches a sagittal plane through the base of the right tentacle, and then anteriorly nearly to the front of the mantle cavity. Here it bends posteriorly and to the left, and enters the right edge of the

verge. The raised ridge on the floor of the mantle cavity is nearly semicircular in cross-section, slightly sinuous in its course, and but slightly larger in diameter than the vas deferens. Seemingly the vas is simply applied to the floor of the mantle cavity, rather than lying beneath it as is the case in all other known Hydrobiidae. An observer can look into the mantle cavity of a living snail that is suitably extended out of the shell, and see even at low magnification the shimmering light refracted from cilia beating in the vas deferens before it enters the verge.

The verge (Text figure 21) is a large organ nearly filling the mantle cavity. It consists of a dorso-ventrally flattened, transversely wrinkled base; a small, glandular accessory process on the left; and a tubular structure as long as or longer than the base that is the free part of the penis.

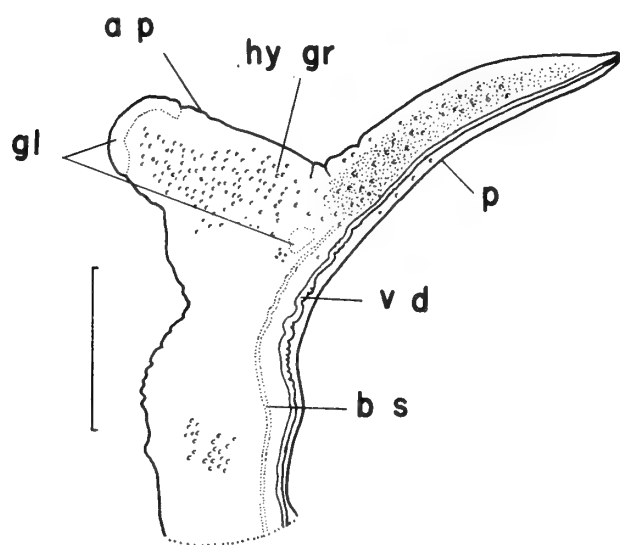


Figure 21

Verge of *Nymphophilus minckleyi* TAYLOR, gen. et spec. nov., dorsal view. Scale line = 1 mm. a p - accessory process; b s - blood sinus; gl - glandular area; hy gr - hyaline granule; p - free part of penis; v d - vas deferens.

The base of the verge is inserted transversely on the floor of the mantle cavity, with the left edge slightly to the left of the median plane. The right edge is in a sagittal plane through the left side of the base of the right tentacle, and slightly posterior to the left edge of the verge. The width of the verge base is about 5 times its antero-posterior thickness.

The verge is normally carried pointing normal to its attachment. Thus, owing to the oblique insertion, the accessory process points forward between the tentacles while the free part of the penis points to the right of the right tentacle. As observed in living specimens, the penis is more mobile and distensible than in any other Hydrobiidae studied. In correlation with the ability to lengthen and move is the occurrence of a discrete blood vessel running to the left of the vas deferens through the base of the verge into the free penis. Such a vessel, appearing as a second tube in the verge, is unknown in other Hydrobiidae.

The base of the verge is unpigmented, very pale gray, and transversely wrinkled. Large yellowish hyaline granules may be clumped near the insertion. The smaller, translucent granules in the accessory process and free penis are not evident in the base.

The short accessory process is unpigmented but contains scattered translucent hyaline granules. The distal end is made up of glandular tissue, appearing milky and nearly opaque. The glandular area may consist of a single band along all of the distal end of the accessory process, or it may be separated into 2 or 3 discrete areas. In one instance a small glandular area occurred also at the base of the accessory process. The process is flattened dorso-ventrally, and is about as thick as the base of the verge, or about 4 times as wide as thick.

The free part of the penis is superficially coated with a dust of fine melanin granules that give it a light ochre color, similar to that of the external parts of the body. It contains numerous scattered translucent hyaline granules like those in the accessory process. The free penis is circular in cross-section, with the vas deferens close to its right side and opening at the tip through a simple pore.

**Eggs.** Only 2 egg capsules were found, both on the shells of living *Nymphophilus*. *Nymphaea* leaves collected in the hope of finding eggs yielded none. The capsules were hemispherical, smooth with no evident surface texture, and appressed to the shell surface with no evident special attachment area. Each was about 0.55 mm in diameter, 0.4 mm high, and contained a single embryonic snail.

**Habitat.** *Nymphophilus* was found alive at 7 localities. At all but one of these the water-lily *Nymphaea* was present, and *Nymphophilus* was most common or found only on the under sides of the lily pads characteristically at a depth of 0.5 m or more. In the laguna west of Río Churince (Text figure 2, locality 9) no water lilies were seen. Here *Nymphophilus* was found only on the lower surfaces of limy algae masses and tufa, in a habitat like that where some specimens were found in West Laguna in El Mojarral (Text figure 2, locality 5).



**Food and feeding.** The *Nymphaea* leaves on which *Nymphophilus* was common were seen in the field to have holes of irregular shape and up to about 10mm long. Both leaves and snails were brought to the laboratory, but the snails did not survive the trip long and no definite observations could be made. In the laboratory the snails did eat fresh lettuce, from which it seems possible that they do eat lily pads rather than merely browse on the epiphyton.

**Etymology.** The species is named in honor of W. L. Minckley, Arizona State University, Tempe, Arizona, U. S. A.

#### *Pomatiopsinae*<sup>10</sup> STIMPSON, 1865

Verge with only 1 duct, the vas deferens (contrast *Aminicolinae* and *Fontigentinae*), without accessory processes. Eyes in relatively prominent bulbous swellings on the outer bases of the tentacles, set off anteriorly by a slight crease (contrast all other subfamilies). Pigmentation consists only of melanin; no yellow granules are present in the head-foot (contrast (*Lithoglyphinae*). Operculum corneous, paucispiral (contrast *Cochliopinae*, *Lyogyrinae*, *Nymphophilinae*). Shell turritiform, phaneromphalous; aperture simple or with a varix. Eggs are laid singly in smooth capsules coated with a husk of mud. The sides of the head-foot are subdivided by 2 prominent grooves: a longitudinal groove begins at the base of the rostrum and runs posteriorly beneath the operculigerous lobe; the other, oviducal groove extends ventrally along the sides of the body stalk as in other subfamilies, but terminates abruptly at the longitudinal fold. Progression is step-wise, in correlation with an amphibious or terrestrial habitat (contrast other subfamilies). Central tooth of radula with 2-3 basal cusps borne on antero-posterior ridges, not on a lateral angle (contrast all other subfamilies). Cusps of lateral and marginal teeth few in number for *Hydrobiidae* (3-11 marginal cusps).

The scope of the *Pomatiopsinae* has been increased since STIMPSON (1865) defined the group, but his original diagnosis is substantially valid. GILL (1871) and a few later authors (for example F. C. BAKER, 1928; E. G. BERRY, 1943) have ranked *Pomatiopsinae* as a family, but I concur with DAVIS (1965) that subfamily rank is more appropriate.

Three characters of the *Pomatiopsinae* are especially distinctive: the longitudinal groove along the sides of the body, the position of the basal cusps of the central tooth, and the prominent eye-swellings. Additional morpholog-

ical data on many Rissoacean groups will be necessary to assess these characters, but some suggestions to stimulate further research are worthwhile.

The longitudinal groove along the sides of the body is unknown in other *Hydrobiidae*, but reminiscent of a similar groove in the *Assimineidae*. Unless this groove can be ascribed plausibly to parallel adaptation to the semiaquatic environment in which both groups generally live, the probability of common inheritance of this character should be considered.

The basal cusps of the central tooth have a location and morphologic origin different from that in all other *Hydrobiidae*, and hence they are probably not homologous. Perhaps then the radula of *Pomatiopsinae* has been derived from one lacking basal cusps, i. e., from a family other than *Hydrobiidae* as defined herein. In considering the radula of *Pomatiopsinae*, one should recall that the radula of *Bithyniidae* (a family profoundly different from *Hydrobiidae* in many characters) is more like that of most *Hydrobiidae* than is the radula of *Pomatiopsinae*.

The prominent swellings in which the eyes are borne are unlike those of other American *Hydrobiidae*. STIMPSON (1865) described *Potamopyrgus* as having the eyes in prominent tubercles, but no comparison of that genus with *Pomatiopsinae* nor detailed description has been published.

**Referred genera** (references are available in WENZ, 1938 to 1944, or in the bibliography of this paper):

*Blanfordia* A. ADAMS, 1863. Japan.

*Oncomelania* GREDLER, 1881 (including *Schistosomophora* BARTSCH, 1936). Eastern Asia.

*Pomatiopsis* TRYON, 1862. U. S. A.

*Tomichia* BENSON, 1851. South Africa.

#### Unnamed subfamily?

Shell turritiform, with an expanded outer lip.

Referred American genera: *Emmericiella* PILSBRY, 1909. San Luis Potosí, México (2 species).

*Pterides* PILSBRY, 1909. San Luis Potosí, México (3 species).

A number of European genera, particularly in the Balkans, share the unusual character of an elongate, turritiform to aciculate shell with a flaring aperture. These may form a group that can be usefully named, but until more is known of their anatomy formal establishment of the group would be unwise. PILSBRY (1909) interpreted *Pterides* as a relative of such forms as *Lartetia*, with which I agree; but he referred *Emmericiella* to *Emmericia* as a subgenus, thus to the *Emmericiinae* in *Micromelaniidae*. Judging entirely from illustrations *Emmericiella* is more similar to such *Hydrobiidae* as *Plagigeyeria* and *Microsal-*

<sup>10</sup> The differentia and scope of this group have been mainly accepted from the work by DAVIS (1965).

*pinx* than to *Emmericia*; and I hesitate to recognize Micromelaniidae in North America on such slender grounds as *Emmericiella* alone.

*Lartetia* was cited by MORRISON (1949) as occurring in eastern North America, but no descriptions or illustrations of the species have been published.

#### HYDROBIIDAE?

#### *Mexithaumatinae* TAYLOR, new subfamily

**Diagnosis.** Shell globose, helicoid, up to about 7.5 mm long with  $4\frac{1}{2}$  whorls, anomphalous. Sculpture consists of about 10-12 spiral cords spaced at nearly equal distance; with increase in size of the shell the number of cords increases by intercalation. The periostracum is brown between cords. On each cord the periostracum is produced into a very dark brown, nearly black, spiral ridge bearing a linear series of short bristles. Operculum plane, corneous, paucispiral. Mantle edge with low papillae, each corresponding to a cord on the shell. Eyes in outer bases of the tentacles, closer to the base and in a less conspicuous swelling than usual in Hydrobiidae. No concentration of hyaline granules around the eye, as is usual in Hydrobiidae. Tentacles with a dorsal lengthwise stripe of melanin, from just beyond the eye nearly to the tip. The verge (Text figure 22) is simple, with no accessory glands or

ducts; it has a narrow distal moiety in which the vas deferens is narrower than in the broader base. The pallial oviduct runs parallel to the rectum, then turns ventrally and posteriorly to the floor of the mantle cavity. The snails are ovoviviparous.

**Referred genera.** *Mexithauma* TAYLOR, gen. nov., is the only included genus.

**Discussion.** There are a number of unique and unusual features of this snail. Evidently it is not much like any known Hydrobiidae, and for convenience in defining that family, *Mexithauma* ought to be excluded. Yet there are no clear evidences of relationship to any other neighboring Rissoacean family, so for the present this snail is left in the Hydrobiidae by default.

Three important characters of *Mexithauma* are otherwise unknown in the Hydrobiidae. These are the papillose mantle border, the reflected end of the pallial oviduct, and the bristly periostracum. I am not certain that analogous characters outside the Rissoacea are of great significance, but it is worth noting that one of the long-time distinctions between Pleuroceridae and Thiaridae (Cerithiacea) is that the former has a plain, the latter a papillose mantle border. The lower course of the oviduct is anomalous; a similar condition is unknown in the other Rissoacea. The surface texture of the periostracum seems to be a weighty character. In only 1 genus described in the Hydrobiidae is the periostracum not smooth-textured: *Antroselates* HUBRICHT (1963). This genus has a central tooth of the radula without basal denticles, and hence I

#### Explanation of Plate 18

*Mexipyrus* from the Valley of Cuatro Ciénegas, Coahuila.

Photographed by K. Sakamoto.

- Figures 46 to 49, 51 to 53: *Mexipyrus mojaralis* TAYLOR, spec. nov.  
46, 47. Type, UMMZ 220192. Length 4.0 mm, width 2.4 mm,  $5\frac{1}{2}$  whorls.  
48, 49. Figured specimen, UMMZ 220193. Length 4.0 mm, width 2.4 mm,  $5\frac{1}{2}$  whorls.  
51. Figured specimen, UMMZ 220193. Length 3.9 mm, width 2.0 mm,  $5\frac{3}{4}$  whorls.  
52, 53. Figured specimen, UMMZ 220193. Length 3.7 mm, width 2.0 mm, 6 whorls.

- Figures 50, 54 to 57: *Mexipyrus multilineatus* TAYLOR, spec. nov.  
50. Figured specimen, UMMZ 220198. Length 4.3 mm, width 2.3 mm,  $6\frac{1}{4}$  whorls.  
54. Type, UMMZ 220197. Length 5.2 mm, width 2.8 mm,  $6\frac{1}{2}$  whorls.  
55. Figured specimen, UMMZ 220198. Length 4.9 mm, width 2.2 mm,  $6\frac{1}{2}$  whorls.  
56, 57. Figured specimen, UMMZ 220198. Length 4.5 mm, width 2.2 mm, 6 whorls.

#### Explanation of Plate 19

*Mexithauma quadripaludium* TAYLOR, gen. et spec. nov. from the Valley of Cuatro Ciénegas, Coahuila.

Drawn by John Tottenham.

- Figures 58, 59: Figured specimen from Laguna Churince, UMMZ 220153. Length 7.7 mm, width 5.9 mm,  $4\frac{1}{2}$  whorls.  
Figures 60, 61: Figured specimen from Laguna Churince, UMMZ 220153. Length 6.6 mm, width 5.7 mm,  $4\frac{1}{2}$  whorls.  
Figures 62, 63: Type from Laguna Tío Candido, UMMZ 220214. Length 6.0 mm, width 5.25 mm,  $4\frac{1}{2}$  whorls.



Figure 46

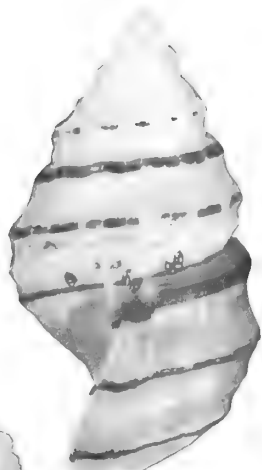


Figure 47



Figure 48



Figure 49

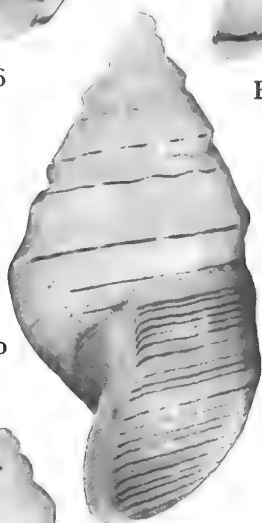


Figure 50



Figure 51



Figure 52



Figure 53



Figure 54

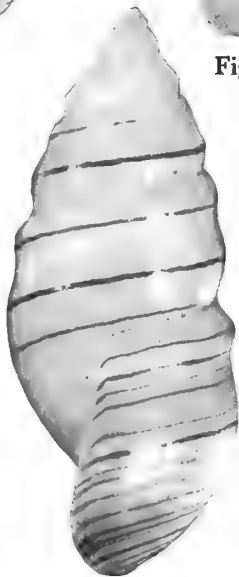


Figure 55

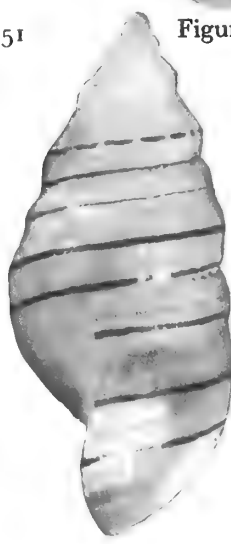


Figure 56



Figure 57



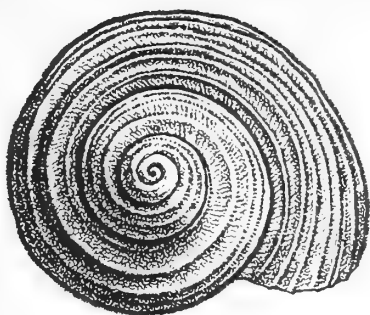


Figure 58

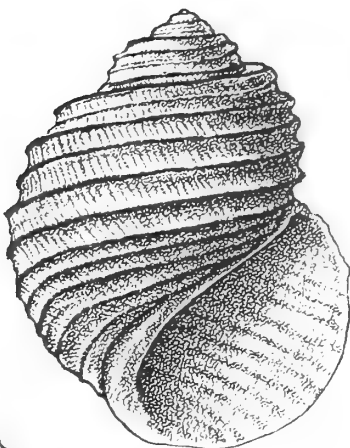


Figure 59

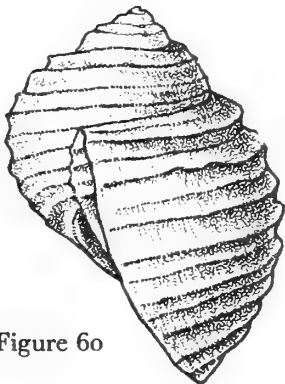


Figure 60

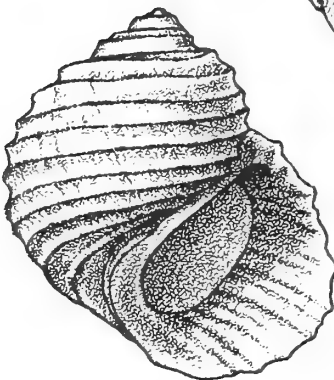


Figure 61

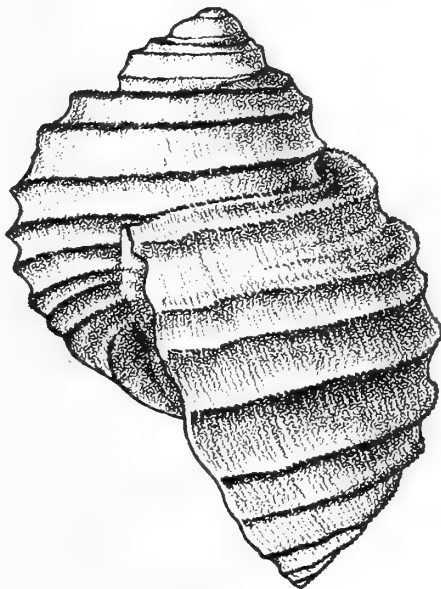


Figure 62

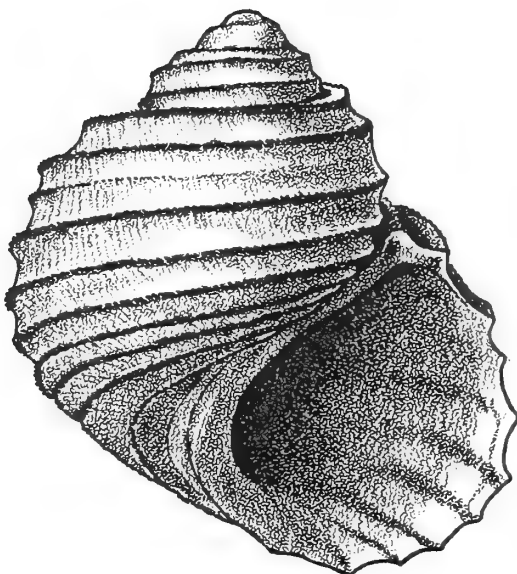


Figure 63



think it should be classified in the Micromelaniidae. Perhaps a rough or bristly periostracum will eventually turn out to be a significant, even if remote, link between *Antroselates* and *Mexithauma*.

Some other features of *Mexithauma* are certainly distinctive, but their taxonomic value is difficult to assess. The stripe along the dorsal surface of the tentacles is a feature I have not seen in any other Hydrobiidae, where the tentacles are either solidly pigmented, or have transverse bars of pigment, or an interior rod-like pigmented region. The numerous spiral cords on the shell are also unusual and might be significant. Sculpture in general is subdued in Hydrobiidae, and only one described genus of Hydrobiidae has numerous cords: *Rachipteron* THOMPSON (1964). Other features of this snail seem so different that I believe it is far better considered as one of the Rissoidae or Stenothyridae.

*Mexithauma* TAYLOR, gen. nov.

**Diagnosis.** Same as for the subfamily.

**Type.** *Mexithauma quadripaludium* TAYLOR, spec. nov.

Only the type species is included in the genus. It is known from several lagunas in the valley of Cuatro Ciénegas, Coahuila, México.

**Etymology.** The name is derived from México; and the Greek word *thauma*, *thaumatous*, a marvel or wonder: hence, a marvelous Mexican mollusk.

*Mexithauma quadripaludium* TAYLOR, spec. nov.

(Plate 19, Figures 58 to 63; Text figure 22)

**Diagnosis.** Same as for the genus and subfamily.

**Type.** UMMZ 220214. Coahuila, México: Laguna Tío Candido, 14 km south of Cuatro Ciénegas. D. W. Taylor, 15-IV-1965. Other specimens from the same collection are UMMZ 220215. The locality is number 8 on Text figure 2.

**Localities and material examined** (listed in geographic sequence around Sierra de San Marcos, beginning at the southwest).

Laguna Churince, 16 km SW Cuatro Ciénegas; D. W. Taylor, 12-IV-1965 (UMMZ 220153, figured specimens; 220152).

Pozos de la Becerra, 14 km SW Cuatro Ciénegas; C. L. Hubbs, 6-IV-1961 (UMMZ 220174); W. L. Minckley, 28-XII-1964 (UMMZ 220171); D. W. Taylor, 14-IV-1965 (UMMZ 220168).

West Laguna in El Mojarral, 1.7 km ENE of tip of Sierra de San Marcos; D. W. Taylor, 13-IV-1965 (UMMZ 220195).

East Laguna in El Mojarral, 1.9 km ENE of tip of Sierra de San Marcos; D. W. Taylor, 13-IV-1965 (UMMZ 220200).

<sup>11</sup> Laguna Escobeda, 12 km S of Cuatro Ciénegas; W. L. Minckley, 31-XII-1964 (UMMZ 220209); D. W. Taylor, 15-IV-1965 (UMMZ 220206).

<sup>12</sup> Laguna Tío Candido, 14 km S Cuatro Ciénegas; D. W. Taylor, 15-IV-1965 (UMMZ 220214, 220215).

**General form, locomotion, behavior.** The globose shell 6-8 mm long in adults is borne free of the substratum with the apex directed upward and posteriorly to the right, so that the axis of the shell forms an angle of about 45° with the long axis of the foot. In dorsal view when the snails are crawling the tip of the snout, and most of the length of the tentacles are visible in front of the shell. The posterior end of the foot and the eyes are not visible in this view, but the anterior corners of the foot may be seen as the snail turns from side to side. Compared to Hydrobiidae seen the snails crawl slowly. The animal cannot right itself when turned on its back.

The tentacles are thick at the base, taper to slender tips and are about 3/4 the length of the shell aperture. The cilia are not arranged in a definite pattern. The tentacles are borne diverging at an angle of about 90°, and usually are in vertical or horizontal movement. They move both above and below a plane parallel to the substratum, and often touch the substratum as if sensing it. In crawling the snail keeps its snout appressed to the substratum, and moves it from side to side while browsing. The movement of the radula can be seen dimly within the snout.

**Pigmentation.** The ground color of the body is pale gray. The dorsal and lateral surface epithelium contains variably dense concentrations of fine melanin granules. Where dense, these granules form dark brown bands like those of the shell. Calcareous granules, much larger than the melanin granules, are conspicuous in the upper anterior parts of the body—in the front end of the foot, in the tentacles, and upper part of the rostrum. Here they lie beneath the surficial melanin granules and appear yellowish. Calcareous granules also are abundant in the mantle collar and posterior part of the body stalk, where they appear white and opaque.

The most heavily pigmented areas, appearing very dark brown, are the tentacles and the edges of the foot. The dorsal surface of the tentacles bears a diffuse-edged band of melanin, from nearly the tip posteriorly to just above the eye. Calcareous granules are scattered within the ten-

<sup>11</sup> Population extinct.

<sup>12</sup> Population studied from living specimens as well as relaxed, fixed material.

tacle, but there is no concentration around or behind the eyes, as is usual in Hydrobiidae.

The lower edges of the foot are heavily dusted with melanin granules that end sharply at the edge of the sole, thus forming a conspicuous lengthwise band. This band may be continuous around the hind end of the foot beneath the operculum, or broken up into variably dense patches. Anteriorly the band is wider and more diffuse on the front end of the foot.

The dorsal part of the head-foot is dusted with melanin, but less intensely than are the tentacles or edges of the foot. The melanin coats the dorsal and lateral surfaces of the snout, continuing posteriorly onto the back of the head and floor of the mantle cavity, and below the tentacular bases and eyes onto the upper sides of the foot. Melanin ends abruptly at the central side of the snout and below the eyes, so that the eyes are partly enclosed and set off by the pigmented area. The melanin becomes less dense and fades out gradually toward the anterior end of the snout, the upper surface of the tentacle bases, the sides of the foot, and within the mantle cavity. There are two areas thus left without melanin – a diffuse broad band on each side of the foot including the operculigerous lobe, and a small area around and above the eye in the bases of the tentacles.

The mantle collar is densely suffused with melanin, but mostly on the surface toward the shell and away from the observer looking into the mantle cavity. Thus the large calcareous granules in the collar stand out white in contrast.

The sole is pale gray, with a faint network of irregular, variably continuous darker gray melanin-pigmented areas within. These pigmented areas largely obscure the abundant translucent hyaline granules scattered in the tissue.

**Head-foot mass.** The foot is not quite twice as long as wide. It is broadly rounded at the hind end, with gently convex sides, and 2 auriculate, mobile lobes at the anterior corners that are set off from the posterior part by a shallow constriction. An anterior pedal groove traverses the anterior edge of the foot.

The highly contractile snout is about  $\frac{1}{3}$  as wide as the foot, flattened-oval in cross-section, and more convex dorsally. It tapers anteriorly more rapidly than in most Hydrobiidae seen. Two fleshy pads at the end of the snout together form a roughly oval area in anterior view, narrower dorsally. They are divided in the median plane by the slit of the mouth, and set off from the rest of the snout by a narrow constriction. The pads are pale gray and less translucent than adjacent parts of the snout. Unlike many Hydrobiidae studied, the pigment of the snout ends diffusely behind these pads, and not abruptly at their edges.

The eyes are in the lateral aspect of the bases of the tentacles. Their position differs from that usual in Hydrobiidae, in being closer to the base of the tentacle and within a low swelling less conspicuous than typical.

The mantle edge is not smooth, as in all other Hydrobiidae known, but bears low projecting papillae that fit into the grooves along the edge of the aperture, beneath the external ridges in the shell. No pattern of granules or pigment was correlated with the undulation of the mantle edge.

**Verge** (Text figure 22). The large verge fills most of the mantle cavity in the male. The broad insertion is transverse, from a little to the left of the median plane to

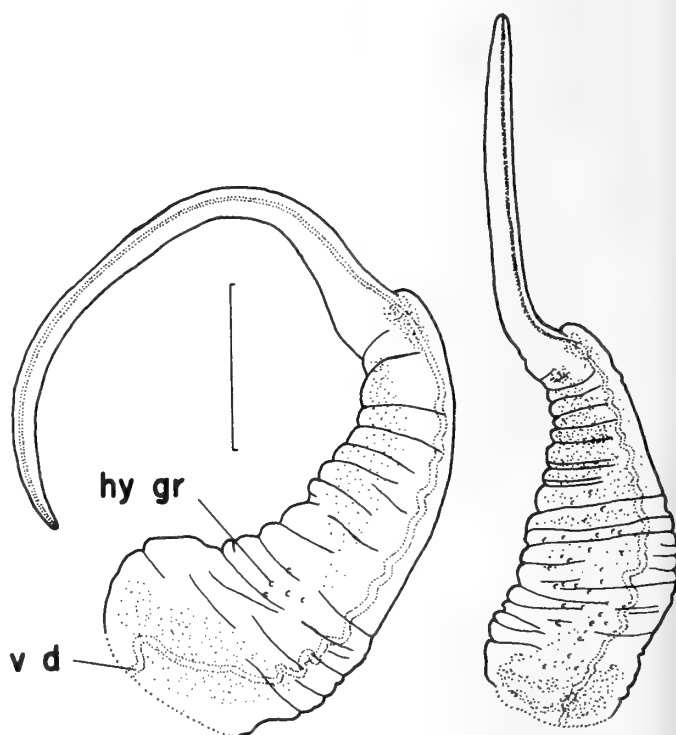


Figure 22

Verges of *Mexithauma quadripaludium* TAYLOR, gen. et spec. nov., dorsal view. Scale line = 1 mm. hy gr - hyaline granule; v d - vas deferens.

a sagittal plane through the base of the right tentacle. The broad proximal part is curved to the left and ordinarily carried so that it ends shortly within the aperture. The slender distal part extends posteriorly into the mantle cavity from an "elbow" where it originates on the proximal part of the verge. The distal part may be carried straight, or coiled through 360°, but the tip of



the verge ordinarily points to the rear of the mantle cavity.  
**Etymology.** The name *quadripaludium* is the Latin translation of "de las cuatro ciénegas" or "of the four marshes."

#### HYDROBIIDAE?

#### *Paludiscalinae* TAYLOR, new subfamily

**Diagnosis.** Shell turritiform, about 2.1 - 2.5 mm long, 1.0 to 1.2 mm wide, with  $6\frac{1}{2}$  -  $7\frac{1}{2}$  whorls ovate in cross-section and separated by a deeply incised suture. Sculpture consists of opisthocyrt lamelliform costae, about 12 per whorl, that are crescentic in profile and highest on the shoulder of the whorl. Base narrowly phaneromphalous. Aperture ovate, in adult shells simple, with no flare of outer lip or callus inside; simply adnate to preceding whorl. Apex blunt; protoconch of 1 whorl, smooth.

**Referred genera.** *Paludiscala* TAYLOR, gen. nov., is the only included genus.

**Discussion.** The spectacular little snails described here as *Paludiscala*, gen. nov., obviously represent a distinctive group within a known family, or even a new family. At first sight they are strikingly like Epitoniidae, on account of the white color, turritiform shape and widely spaced lamelliform costae. Epitoniidae are all marine, several times as large as *Paludiscala*, and usually have whorls more nearly circular in cross-section.

Another group that is slightly reminiscent of *Paludiscala* is Truncatellidae, a group of snails living on land, either inland or above high-tide mark. They are closer in size to *Paludiscala* than are Epitoniidae, but in all known

genera the apex is broken off and the upper end of the shell plugged with a limey deposit.

The size, shape, and inland habitat lead me to think the genus is one of the Rissoacea, but until the anatomy is known, no precise allocation will be possible.

#### *Paludiscala* TAYLOR, gen. nov.

**Diagnosis.** Same as for the subfamily.

**Type.** *Paludiscala caramba* TAYLOR, spec. nov.

Only the type species is included in the genus. It is known only from the type locality, in the valley of Cuatro Ciénegas, Coahuila, México. Even the habitat is uncertain, as the snails might live either in wet places in the marshes, or in the springs proper.

**Etymology.** The name is from the Latin words *palus*, *paludis*, a marsh; and *scala*, literally a staircase, in reference to the generic name *Scala*, by which many Epitoniidae were once known.

#### *Paludiscala caramba* TAYLOR, spec. nov.

(Plate 13, Figures 11, 14, 16; Text figures 23 to 25)

**Diagnosis.** Same as for the genus and subfamily.

**Type.** UMMZ 220164. Coahuila, México: spring tributary to the area of marshes and lagunas named "El Mojarral," 1.7 km due east of the northern tip of Sierra de San Marcos, 11 km southwest of Cuatro Ciénegas. W. L. Minckley, 13-IV-1965. The same collection yielded 18 other specimens; 2 of these are figured (UMMZ



Figures 23 to 25

*Paludiscala caramba* TAYLOR, gen. et spec. nov.

Figure 23: Figured specimen, UMMZ 220165. Length 2.6 mm; width 1.4 mm;  $6\frac{1}{2}$  whorls.

Figure 24: Figured specimen, UMMZ 220165. Length 2.3 mm; width 0.9 mm;  $7\frac{1}{4}$  whorls.

Figure 25: Type, UMMZ 220164. Length 2.5 mm; width 1.2 mm;  $7\frac{1}{2}$  whorls.

220165), 16 unfigured (UMMZ 220163). The locality is number 1 on Text figure 2.

**Material.** The collection came from the soft black organic mud of a small spring, where *Durangonella* sp. was abundant. None of the snails, either *Paludiscala* or *Durangonella*, was alive, nor freshly dead so as to retain traces of the body, or operculum. Many of the *Durangonella* retain the periostracum, and only a few are bleached chalky white, as are all specimens of *Paludiscala*. If *Paludiscala* lived along with *Durangonella* in this spring, then probably it has a thinner periostracum, or virtually none.

**Variation.** The chief variation is in length/width ratio, and strength and spacing of costae. Size, cross-section of whorl, and apertural characters are more constant. The extremes of width are 1.0 and 1.2 mm, both found in shells 2.1 mm long. The figured specimens were selected to show variation in both shape and in sculpture.

The costae are not arranged in a consistent pattern, and their number per whorl does not even increase regularly with growth. The number on the body whorl is 11 - 16; on the preceding whorl, 9 - 14; and on the one before that, 7 - 16. Generally the number of costae on a given whorl is greater than that on the preceding whorl, but even this is not invariable.

A common variation in spacing and strength of costae occurs in the first and last quarter-whorls of the teleoconch. The smooth protoconch (with no sculpture evident at 50x magnification) is set off from the teleoconch by costae that are lower and more closely spaced in the first quarter-whorl of post-embryonic growth than later. Similarly, costae on the last quarter-whorl of the body whorl are more crowded and lower than previously. This is the only evidence of determinate growth; there is no descent of the suture, loosening of the body whorl, apertural callus, or terminal flare of the aperture as in some Rissoacean snails.

**Etymology.** ¡caramba!, an exclamation, loosely translated from my original remarks at seeing the shells. An epitoniid-like snail in the arid interior of northern México is thoroughly implausible.

#### ASSIMINEIDAE

*Assiminea* FLEMING, 1828

*Assiminea* sp.

Five specimens (UMMZ 220176), all but one worn and lacking periostracum, were found in a bottom sample from the northernmost pool of Pozos de la Becerra, 14 km southwest of Cuatro Ciénegas, collected by C. L. Hubbs, 6-IV-1961. The species is almost certainly new, but I defer description in the hope of obtaining more material in better condition, hopefully alive. Most species of *Assi-*

mineidae are at least semiterrestrial, so that this Mexican species probably lives in wet marshy areas around the spring-pools, not in the springs proper. This habitat has never been searched by a malacologist in the Cuatro Ciénegas valley, and hence there is hope for finding *Assiminea* there alive.

In America the species of Assimineidae are few compared to the number in eastern Asia, and they are best known from near high-water mark along the coast, or in salt marshes. The only inland occurrences of *Assiminea* previously recorded in North America are in the Death Valley region of southeastern California, U. S. A. S. S. BERRY (1947) described *A. infima* from "Bad Water," the salt-saturated pool below sea level that is the lowest point on the continent. MORRISON (1956) has suggested another species lives around Saratoga Springs, at the south end of Death Valley.

Still another undescribed species of *Assiminea* of inland habitat is represented in U. S. Geological Survey collections from Panamint Valley, Inyo County, California. This valley is the one next west from Death Valley, and like Death Valley it has scarcely been explored by a malacologist. Hence there is a real possibility that *Assiminea* still lives there. Precise locality data for the fossil occurrence are as follows:

U. S. Geological Survey Cenozoic locality M2617. Inyo County, California. Panamint Butte quadrangle (1951) 1:62500. 1000 feet east, 700 feet south of northwest corner, sec. 14, T. 18 S., R. 42 E. Archeological site Iny-19, from within and below organic mat dated  $10520 \pm 140$  years B. P. (UCLA-990), about six feet below surface in bulldozer trench exposure. Collected by E. L. Davis, University of California at Los Angeles.

In the light of these inland occurrences in southwestern California and central Coahuila, one may suppose *Assiminea* will be found at other places in the scarcely known interior of northern México.

Species of *Assiminea* are most diversified in eastern Asia. In addition to the small, plain, brown-shelled forms that ABBOTT (1958) called the "nitida-complex" (including all the American species) there are larger, more sculptured species and some with color bands. This greater morphological diversity is not correlated with greater ecological range than in America. ABBOTT (1958) found that in the Philippines *Assiminea* is a coastal and brackish-water group. One species, *A. thielei*, lives in fresh water most of the year and will not tolerate submersion in saline waters; it is the most nearly freshwater species in the region. In New Guinea JUTTING (1963) noted that one species, *A. riparia*, had the unusual habit of living on the bank of a freshwater lake; other species in the area live in brackish-water and coastal habitats.

## BASOMMATOPHORA

## LYMNAEACEA

## LYMNAEIDAE

*Fossaria* WESTERLUND, 1885*Fossaria obrussa* (SAY, 1825)

PILSBRY (1904: 777) recorded "*Limnaea desidiosa* SAY" from Saltillo, Coahuila. The record was assigned by F. C. BAKER (1911) to *Fossaria obrussa*, perhaps the most widely distributed lymnaeid in North America.

## ANCYLACEA

## ANCYLIDAE

*Gundlachia* PFEIFFER, 1849*Gundlachia excentrica* (MORELET, 1851)

One empty but well preserved shell is identified as this species in the sense of WALKER (1903), both from that paper and comparison of specimens. The species is known from southern Texas, U. S. A., southward to Guatemala.

Assignment of the species to *Gundlachia* is based on the conclusions of HARRY & HUBENDICK (1964), who included the West Indian *Gundlachia radiata* (GUILDING) within the genus. That species was recognized as similar to *G. excentrica* (MORELET) by WALKER (1903), and the 2 were even synonymized by WURTZ (1951). BASCH (1963) assigned the species to *Hebetancylus*.

**Locality and material examined.** Coahuila, México: Río Salado de los Nadadores at El Cariño de la Montaña, 20 km east of Cuatro Ciénegas; D. W. Taylor, 12-IV-1965 (UMMZ 220148).

## PLANORBIDAE

The primary work on Planorbidae is that by F. C. BAKER (1945); Mexican locality data therein have been indexed by DRAKE (1948). More recent work on tropical American Planorbidae is accessible through papers by HARRY (1962) and HARRY & HUBENDICK (1964).

## Drepanotrematinae?

*Drepanotrema* CROSSE & FISCHER,  
1880?

Three tiny shells (UMMZ 220179), all broken and lacking periostracum, may belong to the genus *Drepano-*

*trema*. They are tightly coiled, planispiral, and more like *Drepanotrema* than *Gyraulus*, *Antillorbis*, *Promenetus*, or other small Planorbidae that might occur in the region. The specimens were in a bottom sample from the northernmost pool of Pozos de la Becerra, 14 km southwest of Cuatro Ciénegas, collected by C. L. Hubbs, 6-IV-1961.

## Helisomatinae

*Helisoma* SWAINSON, 1840*(Helisoma)* s. s.*Helisoma* (s. s.) *anceps* (MENKE, 1830)

Specimens found in a spring beside Río de los Nadadores, at El Cariño, are typical of the widespread creek form of the species, and show no differences worthy of taxonomic separation. The nearest records are in the spring-fed streams along the edge of the Balcones Escarpment, in central Texas. Suitable habitats for the species are doubtless sparse in the arid regions of northern México and the southwestern United States, so that its distribution is widely discontinuous. MILSTEAD (1960) summarized the distribution of some amphibians whose range is similarly discontinuous in the region. Perhaps some of their ranges may prove closely similar to that of *Helisoma anceps* when more mollusk collections are known.

In summarizing the distribution of this species, WALKER (1909) found it is widespread throughout central and eastern North America, and occurs sparsely in the Pacific Northwest. He doubted the record in Sonora, at the mouth of the Yaquí River, but F. C. BAKER (1945: 402 to 403) illustrated a specimen from that locality. This was the only previously known occurrence of *Helisoma anceps* in México.

Specimens: UMMZ 220146.

## PHYSACEA

## PHYSIDAE

*Physa* DRAPARNAUD, 1801*(Physella)* HALDEMAN, 1842

The original criteria for establishment of *Physella* were trivial, as noted by F. C. BAKER (1928: 416), but the name is the earliest one applicable to the group of species with an acute (not rounded) apex, and mantle unreflected over the outer lip. MARTENS (1890-1901: 368) evidently had much the same group in mind when he proposed *Alampetis* (preoccupied). At least in the present state of knowledge I see no reason to recognize 2 separate sub-

groups, so that *Alampetis* MARTENS (1898), *non* THOMSON (1878), and *Alampetista* ZILCH (1956) are included as synonyms.

In identifying the specimens I have from Coahuila, and in dealing with the literature of *Physa* from the region, I have reviewed long series of specimens from the southwestern U. S. A. and northern México. Thanks to considerable field work in the region, as well as extensive material, I have been able to see both type material as well as the range of variation encountered in a variety of habitats. No classification in this genus can be based satisfactorily on shell characters alone, but this is all the previous species have been based on and I have simplified the group and put it on a slightly firmer foundation.

The following forms have been named from southwestern U. S. A. and northeastern México:

*Physa humerosa* GOULD, 1855, Proc. Boston Soc. Nat. Hist. 5: 128. "Colorado Desert [California] and at Pecos River [New Mexico or Texas]." GOULD, 1857, Rep. U. S. Explorations and surveys for a railroad route . . . to the Pacific Ocean, 5 (2): 331, pl. 11, fig. 1 - 5. Type ANSP 17279 (H. B. BAKER, 1964), figured by BINNEY (1865: 92, text-fig. 157). JOHNSON (1964) lists syntypes only from MCZ and USNM collections. In none of these publications is a restricted type locality clear; it is designated here as the Colorado Desert, California.

*Physa virgata* GOULD, 1855, Proc. Boston Soc. Nat. Hist. 5: 128. "River Gila [Arizona], and near San Diego [California]." Type ANSP 17244a (H. B. BAKER, 1964). Lectotype MCZ 72995 (JOHNSON, 1964; the locality San Francisco is an error for San Diego). Perhaps neither one of these type specimens has a precise locality; if so it has not been published. JOHNSON (1964, pl. 44, fig. 5) illustrated the MCZ lectotype.

*Physa traskii* LEA, 1864, Proc. Acad. Nat. Sci. Philadelphia 16: 115. "Rio Los Angeles, California." LEA, 1867, Observations on the genus *Unio* . . . , 11: 119, pl. 24, fig. 80.

*Physa osculans rhyssa* PILSBRY, 1899, Proc. Acad. Nat. Sci. Philadelphia 51: 401. Saltillo, Coahuila, México. Type ANSP 77218a (H. B. BAKER, 1964).

*Physa virgata alba* COCKERELL, 1902, Journ. Malac. 9: 138. Salt River at Tempe, Arizona. Not of CRANDALL, (1901).

*Physa bottimeri* CLENCH, 1924, Nautilus 38: 12, text-fig. 4. Comanche Spring, Fort Stockton, Pecos County, Texas.

*Physa marci* F. C. BAKER, 1924, Nautilus 38: 15, text-fig. 5. Little Valientia Spring, Santa Barbara National Forest, California. The type locality has not been precisely recovered; I cannot find a "Santa Barbara National Forest" nor a spring of that name in the vicinity of Santa Barbara.

*Physa humerosa interioris* "FERRISS" PILSBRY, 1932,

Nautilus 45: 139, pl. 11, fig. 12. West branch of Navajo Creek, Coconino County, Arizona. The name as published originally by FERRISS (1920) is nude, hence it should be credited to PILSBRY as done by H. B. BAKER (1964).

The species of *Physa* in this region can be grouped conveniently into 2 species-groups. In one group the shell attains a larger size, the spire is shorter, and the body-whorl is characteristically shouldered. The work by SPRINGER (1902) indicates some radular differences, but not enough species have been investigated to judge what characters are significant. This is the *lordi*-group of F. C. BAKER (1928: 424). The second group includes species that attain a smaller size, have a shell with longer spire, and are characteristically not shouldered. This may be called the *gyrina*-group after its most widespread species; most *Physella* fall into this species-group.

#### Group of *Physa gyrina*

In previous work (HIBBARD & TAYLOR, 1960: 115 - 121) on *Physa* in the Great Plains region of the United States I recognized that shells of the subgenus *Physella* could be sorted into 2 categories: (a) shells usually larger, with a conspicuous and usually thicker apertural callus, and shorter spire with shallower sutures; more northern in distribution, identified as *Physa gyrina* SAY; (b) shells usually smaller, with a less conspicuous, thinner apertural callus, and longer spire with deeper sutures; more southern in distribution, identified as *Physa anatina* LEA. Since that time I have studied material from more western and southern areas, and collected in a variety of habitats in parts of México and U. S. A. From this experience I find that these same differences hold true from the Great Plains westward to the Pacific Ocean: commonly there is a larger, shorter-spined *Physa* to the north, and a smaller, higher-spined form, often with deep sutures, to the south. The oldest name surely applicable to this southern form is *P. virgata* GOULD (1855). I have reviewed specimens of *Physa* from southern California eastward to Kansas and southward to Texas and México, and examined nearly all the pertinent types, but have not tried to revise the scattered published records from the region.

#### *Physa (Physella) virgata* GOULD

(Plate 14, Figure 18)

In springs and small perennial streams from southern California to trans-Pecos Texas the *Physa* is usually only 8 to 10 mm long, with an aperture  $\frac{2}{3}$ - $\frac{3}{4}$  of the shell length, deep sutures, narrow spire, no shoulder on the body whorl, and no apertural callus. This form is regionally so

similar that surely there is no warrant for recognizing more than one species. With increasing size of the water body the shells may grow larger, and especially in slow-moving streams or ponds they become more swollen. *Physa humerosa interioris* PILSBRY (1932), from Arizona, the *Physa* from New Mexico illustrated by SPRINGER (1902), and *P. traskii* LEA (1864) are of this slightly larger stream form. The formation of an apertural callus is irregular; often there is none at any age. In none of this variation is any geographic pattern evident.

Specimens from northeastern Mexico are scarce in museum collections. UMMZ 123599 includes 4 specimens marked "Cotypes" of *Physa osculans rhyssa* PILSBRY (1899) from Saltillo, Coahuila. These seem to me to be only long-spined shells of *P. virgata*. They can be duplicated at other localities to the north, for example by a larger series (UMMZ 176787) from Old Log Spring, west of The Solitario, Presidio County, Texas, collected by Leslie Hubricht, 30-V-1938. The riblets mentioned by PILSBRY are often found on *Physa*, presumably because of irregular growth in later life, and are not even restricted to *P. virgata* in the broad sense used here. Three lots (UMMZ 122115, 122121, 123600) from Valles, San Luis Potosí, México, collected by A. A. Hinkley, all fall within the range of *P. virgata* to the north, but were labelled *P. osculans*, *P. osculans rhyssa*, and *P. mexicana*. From study of the variation in *Physa* found in different habitats within a small area, I see no evidence for 3 species here, and they are all closer to *P. virgata* in form than to specimens from central México.

In Coahuila thus there seems to be no evidence of more than one *Physa*, *P. virgata*. The record by DALL (1905: 193) of *Physa berendti* DUNKER also is based on *P. virgata* (specimens USNM 110403). The locality "Twenty-five miles southeast of Saltillo" is at least close to the southeastern border of Coahuila, and might be inside that state.

As one traces the variation and distribution of *Physa virgata* eastward from New Mexico and trans-Pecos Texas the shells are commonly larger (15 mm is frequent) and several irregularly spaced apertural thickenings are common, appearing as white collabral bands through the shell. These represent the species I have previously (HIBBARD & TAYLOR, 1960; TAYLOR, 1960) called *Physa anatina* LEA; but there are no reliable shell characters to distinguish it from the southwestern *P. virgata*. The difference in the regional variation I think could be accounted for entirely by differences in the suitable habitats available, but only anatomical studies can resolve this question.

*Physa rhomboidea* CRANDALL (1901) was described in part from specimens from Las Vegas, New Mexico; the type locality is Muddy Creek, Sedalia, Pettis County,

Missouri, U. S. A. The Las Vegas specimens I agree with SPRINGER (1902) are *P. virgata*. The syntypes (originally 40775 of Bryant Walker collection) are UMMZ 130515, and as between *P. gyrina* and *P. virgata* are certainly the latter. A revision of *Physa* in this area is beyond the scope of this study, and other species perhaps distinct from the 2 common western ones should be considered.

In southernmost Texas, around Brownsville, occurs a form that might be an extreme variant of *Physa virgata*, or a distinct species. The shells attain a length of 20 mm, longer than any others seen from the range of *P. virgata*, but are narrow and high-spined as in *P. virgata*.

*Physa marci* F. C. BAKER (1924) from California is probably an ecologic variant of *P. virgata*, but I have not seen either the original material nor topotypes. *Physa virgata* is otherwise the only species in coastal southern California.

**Summary of distribution.** *Physa virgata* is common over most of south-central and southwestern North America. In California it is found at least as far north as Sacramento and San Francisco Bay, and extends thence into northernmost Baja California and eastward. It occurs in southernmost Nevada, southernmost Utah, and Colorado, but northward is replaced by *P. gyrina*. In southern Kansas, and southward perhaps throughout Texas, *P. virgata* is the only living species of the genus. Its range extends eastward an unknown extent; and southward over most of the Mexican Plateau.

**Comparison with species from México.** Only 2 names published prior to *Physa virgata* GOULD (1855) have sometimes been applied to specimens of that species. These are *Physa osculans* HALDEMAN and *P. mexicana* "PHILIPPI" KÜSTER; references to literature and illustrations are accessible through the work by MARTENS (1890 to 1901). Neither of the 2 species was described from a locality more precise than "México"; and in a group so variable as *Physa* one may doubt whether they can be recognized.

USNM 543500 is a single fossil specimen from a peat bed near the village of Tepexpam, Lake Texcoco, D. F., México, collected by A. R. V. Arellano. Its large size, short spire, shallow sutures, and relatively thick shell are features distinct from *Physa virgata* and like those of *P. gyrina*. The specimen could readily be matched in late Pleistocene assemblages from the central United States. This example is significant in confirming the authenticity of Recent specimens with shells like *P. gyrina* from this part of México.

USNM 9009 includes 3 Recent shells identified as "*Physa osculans* HALD. Mexico. A.N.S." They were listed under that name by BINNEY (1865: 83). Lacking a precise locality, they are of value mainly in showing what

was taken as *P. osculans* in that day, but might have been identified by Haldeman and be part of the original lot. These shells are distinguished from *P. virgata* by larger size, and shallower sutures, but in height of spire are not diagnostic. One short-spined specimen is like *P. gyrina*, but the other two are not characteristic in this respect.

UMMZ 123391 is from Tlalpan, near México, D. F., collected by S. N. and M. C. Rhoads, 1899, and labelled *Physa osculans* HALDEMAN. The specimens are short-spined with shallow sutures, and if they were labelled as coming from Ohio or Idaho, for example, I would call them *P. gyrina*. They agree well with the figures of *P. mexicana* published both by MARTENS and KÜSTER, but not so closely with the type of *P. osculans*. At any rate there seems to be a typical *Physa* other than *P. virgata* in central México. Perhaps *P. virgata* and *P. osculans* are one species, but in the absence of a precise type locality I do not see how to establish this. The illustration of the type of *P. osculans* (HALDEMAN, 1840-1844, 6: pl. 2, fig. 11) might be *P. virgata* or *P. mexicana*. In the interest of stability of nomenclature and clarity of understanding, the name *P. osculans* might best be ignored, or at least not used for *P. virgata*.

#### Localities and material examined (Coahuila only).

Rancho San Marcos, 20 km SSW Cuatro Ciénegas; D. W. Taylor 14-IV-1965 (UMMZ 220217) (Plate 14, Figure 18).

Río Mesquites, 9 km SW Cuatro Ciénegas; D. W. Taylor, 13-IV-1965 (UMMZ 220191).

Río Salado de los Nadadores, El Cariño de la Montaña, 20 km E Cuatro Ciénegas; D. W. Taylor, 12-IV-1965 (UMMZ 220147).

Saltillo; S. N. and M. C. Rhoads, 1899 (UMMZ 123599; USNM 160166; paratypes of *Physa osculans rhyssa* PILSBRY).

Twenty-five miles southeast of Saltillo; E. Palmer (USNM 110403).

*Physa (Physella) virgata bottimeri* CLENCH, 1924  
CLENCH (1924) described *Physa bottimeri* from 4 specimens. Two of these I have studied: the holotype (UMMZ 31617) and a paratype (UMMZ 117581) collected by L. J. Bottimer, 14-I-1922, at Comanche Spring, Fort Stockton, Pecos County, Texas. The specimens are markedly distinct by the strongly shouldered body whorl, short spire, and apertural callus.

Two series of topotypes (UMMZ 132522, 132523) collected by C. L. Hubbs, 1938, substantially blur the

distinctiveness of this form. They include both typical *Physa virgata* and forms intermediate between *P. virgata* and *P. bottimeri*. Whether they are only an ecological form or a genetically differentiated relative of *P. virgata* is undeterminable; the type locality has been destroyed and there is no longer a spring there. On account of these annectant forms I am lowering the rank of *P. bottimeri* to subspecies. On account of its distinctiveness it would be unwarranted to relegate it to the synonymy of *P. virgata* as yet.

Four small, immature specimens (UMMZ 66335) are unusual in having incipient shoulders to the body whorl despite their size, and might have grown into shells much like *Physa bottimeri*. They are from the "head spring at Toyahvale, Reeves Co., Texas"; perhaps study at this locality might shed light on *P. bottimeri*.

#### Group of *Physa lordi*

In the southwestern U. S. A. at least 2 species belong to this group: *Physa humerosa* GOULD, and an undescribed species mentioned by SPRINGER (1902) from the Organ Mountains, New Mexico. *Physa humerosa* I consider restricted to southeastern California, southwestern Arizona, and adjacent Baja California. It is most widely represented in museum collections by subfossil specimens from the Colorado Desert, California, where it is now extinct. The only specimens collected alive that I have seen are USNM 29119, 2 shells fresh and retaining periostracum, labelled "Gila River, Arizona;" they were collected by a Dr. Loew, in 1873.

*Physa patzcuarensis* PILSBRY (1891 a), from Lago Patzcuaro, Michoacán, México, might possibly belong to this group; if so it is the most southerly representative. Although described as a variety of *P. osculans*, it seems deserving of specific rank.

## STYLOMMATOPHORA

### SUCCINEACEA

#### SUCCINEIDAE

One broken shell (UMMZ 220155), presumably representing *Catinella* or *Succinea*, was screened from the bottom of the outflow of Laguna Churince. It is the only land snail collected so far in the valley of Cuatro Ciénegas. At this locality no search was made for snails except in water, so live Succineidae can probably be found here.

# TAXONOMIC AND NOMENCLATURAL CHANGES

## NEW CATEGORIES AND NEW RANKS

### HYDROBIIDAE

Cochliopinae, new subfamily, with 3 tribes

Cochliopini, new rank (= Cochliopinae TRYON, 1866), for *Cochliopina* STIMPSON (1865), *Cochliopina* MORRISON (1946), *Lacunorbis* YEN (1950), *Limnothauma* HAAS (1955), *Nanivitreia* THIELE (1927), and *Subcochliopa* MORRISON (1946).

*Cochliopina milleri* TAYLOR, spec. nov.

Horatiini, new tribe, for *Coahuilix* TAYLOR, gen. nov.; *Gocea* HADŽIŠČE (1956a); *Hadziella* KUŠČER (1932); *Horatia* BOURGUIGNAT (1887), including the subgenera *Horatia s.s.*, *Daudebardiella* BOETTGER (1905), *Hauffenia* POLLONERA (1898) and *Neohoratia* SCHÜTT (1961); *Lyhnia* HADŽIŠČE (1956b); *Ohridohoratia* HADŽIŠČE (1956b), including the subgenus *Ohridohauffenia* HADŽIŠČE (1956b); and *Ohrigocea* HADŽIŠČE (1956b), including the subgenus *Karevia* HADŽIŠČE (1956b).

*Coahuilix hubbsi* TAYLOR, gen. et spec. nov.

Clenchiellini, new tribe, for *Clenchiella* ABBOTT (1948)

Fontigentinae, new subfamily, for *Fontigens* PILSBRY (1933)

Lithoglyphinae, new subfamily, for *Lithoglyphus* HARTMANN (1821)

Littoridininae, new subfamily, for *Brachypyrulina* HAAS (1955), *Durangonella* MORRISON (1945), *Ecpomastrum* HAAS (1957), *Heligmopoma* HAAS (1955), *Idiopyrgus* PILSBRY (1911), *Littoridina* SOULEYET (1852), *Littoridinops* PILSBRY (1952), *Lyrodes* DOERING (1884), *Mexipyrus* TAYLOR, gen. nov., *Pyrgophorus* ANCEY (1888), *Rhamphopoma* HAAS (1955), *Strombopoma* HAAS (1955), *Texadina* ABBOTT & LADD (1951), *Tryonia* STIMPSON (1865), and *Zetekina* MORRISON (1947).

*Durangonella coahuilae* TAYLOR, spec. nov.

*Mexipyrus carranzae* TAYLOR, gen. et spec. nov.

*M. churinceanus* TAYLOR, spec. nov.

*M. escobedae* TAYLOR, spec. nov.

*M. lugoi* TAYLOR, spec. nov.

*M. mojarralis* TAYLOR, spec. nov.

*M. multilineatus* TAYLOR, spec. nov.

Nymphophilinae, new subfamily, for *Nymphophilus* TAYLOR, gen. nov.

*Nymphophilus minckleyi* TAYLOR, gen. et spec. nov.

### HYDROBIIDAE?

Mexithaumatinae, new subfamily, for *Mexithauma* TAYLOR, gen. nov.

*Mexithauma quadripaludium* TAYLOR, gen. et spec. nov.

### HYDROBIIDAE?

Paludiscalinae, new subfamily, for *Paludiscala* TAYLOR, gen. nov.

*Paludiscala caramba* TAYLOR, gen. et spec. nov.

## TAXONOMIC CHANGES

### VALVATACEA

#### VALVATIDAE

*Carinorbis utahensis* LAROCQUE, 1960 = *Valvata bicincta* WHITEAVES, 1885

### VIVIPARACEA

Bithyniidae are transferred from Rissoacea

### RISSEOACEA

STENOXYRIDAE, or RISSOIDAE (Stenothyridae)

*Rachipteron* THOMPSON, 1964 is transferred from HYDROBIIDAE

### HYDROBIIDAE

#### Amnicolinae

*Hydrobia greggi* PILSBRY, 1935, is assigned to *Amnicola*

#### Cochliopinae

"*Planorbis*" *bourguyi* ROXO, 1924; "*Planorbis*" *pebasana* CONRAD, 1874; and "*Planorbis*" spec. of DE GREVE, 1938, are probably Cochliopinae instead of PLANORBIDAE

*Carinorbis* YEN, 1946, non CONRAD, 1862 = *Carinorbis* YEN, 1949, is synonymized with *Clenchiella* ABBOTT, 1948

*Valvata kugleri* FORCART, 1948, is assigned to *Cochliopina*



## Littoridininae

- Hydracme* HAAS, 1938 = *Idiopyrgus* PILSBRY, 1911  
*Isaea* CONRAD, 1871 = *Tryonia* STIMPSON, 1865  
*Liris* CONRAD, 1871 = *Tryonia* STIMPSON, 1865  
*Dyris* CONRAD, 1871 = *Tryonia* STIMPSON, 1865  
*Conradia* WENZ, 1925 = *Tryonia* STIMPSON, 1865  
*Potamopyrgus amazonicus* HAAS, 1949 is assigned to *Tryonia*  
*Potamopyrgus? bakeri* PILSBRY, 1891 is assigned to *Tryonia*  
*Pyrgulopsis blakeana* TAYLOR, 1950 = *Tryonia protea* (GOULD)  
*Pyrgulopsis cahuillarum* TAYLOR, 1950 = *Tryonia protea* (GOULD)  
*Potamopyrgus cheatumi* PILSBRY, 1935, is assigned to *Tryonia*  
*Calipyrgula circumstriata* LEONARD & HO, 1960 b is assigned to *Tryonia*  
*Paludestrina curta* ARNOLD, 1903 = *Tryonia imitator* (PILSBRY)  
*Potamopyrgus fagundesii* HAAS, 1938, is assigned to *Tryonia*  
*Calipyrgula hibbardi* LEONARD & FRANZEN, 1944 is assigned to *Pyrgophorus*  
*Paludestrina imitator* PILSBRY, 1899 d is assigned to *Tryonia*  
*Potamopyrgus laciranus* PILSBRY & OLSSON, 1935 is assigned to *Tryonia*  
*Pyrgulopsis? patzcuarensis* PILSBRY, 1891, is assigned to *Tryonia*  
*Calipyrgula pecosensis* LEONARD & HO, 1960 a is assigned to *Tryonia*  
*Hydrobia reevii* FRAUENFELD, 1863, is assigned to *Pyrgophorus*  
*Calipyrgula senta* LEONARD & FRANZEN, 1944, *C. tumida* LEONARD & FRANZEN, 1944, and *C. turricula* LEONARD & FRANZEN, 1944 = *Pyrgophorus hibbardi* LEONARD & FRANZEN, 1944  
*Lyrodes hertleini* DRAKE, 1956, is *incertae sedis*, probably not Littoridininae

## MICROMELANIIDAE

- Antroselates* HUBRICHT, 1963, is transferred from HYDROBIIDAE

## ANCYLACEA

## ANCYLIDAE

- Ancylus excentricus* MORELET is assigned to *Gundlachia*

## PHYSACEA

## PHYSIDAE

- Physa osculans rhyssa* PILSBRY, 1899 = *P. virgata* GOULD  
*Physa anatina* LEA, 1864 = *P. virgata* GOULD  
*Physa marci* F. C. BAKER, 1924, probably is a synonym of *P. virgata* GOULD  
*Physa bottimeri* CLENCH, 1924 is lowered to subspecific rank as *P. virgata bottimeri*  
*Physa osculans patzcuarensis* PILSBRY, 1891, is raised to specific rank

## SUMMARY

The small valley of Cuatro Ciénegas, about 30 by 40 km, in central Coahuila, northeastern México, has yielded the most spectacularly endemic fauna of freshwater snails known in the Western Hemisphere. The scanty collecting so far has been concentrated on only one habitat, the large springs, so that doubtless future additions will be made. Out of about 18 forms, only 13 can be identified specifically. One species is widespread in the region; the other 12 are new endemic species classified in five new endemic genera of which three represent new endemic subfamilies. This remarkably localized fauna shows scarcely any resemblance to known mollusks of eastern México, but the interior plateau of México is so poorly known that perhaps some groups will turn up elsewhere. Recent intensive development of the springs for irrigation has already exterminated some populations, perhaps a few species, and threatens many others in the immediate future.

The nearest parallel in the Western hemisphere to the localized endemism of the Cuatro Ciénegas valley is in Lake Titicaca, Bolivia - Peru. Five genera are restricted to this lake, and another nearly so; all belong to widespread subfamilies and are not isolated taxonomically like the striking endemics in México.

Besides being strongly differentiated from the taxonomic standpoint, four of the new endemic genera are unusual morphologically. In having elaborate sculpture, color banding, a bristly surface, or being of large size for their groups they remind one more of marine snails than the groups to which they are anatomically similar.

Out of five localized new genera, three are known only by shells from one locality each. The other three genera were collected alive at several localities, where they occur as isolated populations showing different degrees of morphological divergence. Two of the genera are not differ-



entiated morphologically, but *Mexipyrus* has undergone remarkable divergence. Seven populations sampled are assigned to six species. The morphological differences between these species are not correlated consistently with geographic location, so that they seem to have diverged through assortment of characters. In spite of the various differences in shape, sculpture, size, and color banding between the *Mexipyrus* species, none shows distinctive characters in the male genitalia, where the most useful taxonomic differentia between populations and species would be expected. Hence divergence of the colonies may not be related to reproductive isolation except through their geographic separation.

Other kinds of animals besides the snails show local endemism, although not as spectacularly. About half of the 20 fish species are restricted to the valley, and one cryptic species is specialized to feed on snails. Three forms of turtles are endemic to the basin; this is the highest concentration of endemism among Testudinata known in North America. One of these forms is a semi-aquatic species of *Terrapene*, a genus that is otherwise terrestrial. In these and other groups now under study, the isolation affects aquatic and marsh-dwelling forms most conspicuously.

No direct fossil evidence is available for judging the length of isolation of the endemic snails of the Cuatro Ciénegas area. If degree of taxonomic divergence is proportional to isolation, then the ancestry of some of the fauna reaches deep into the Tertiary, or Mesozoic. *Mexipyrus*, an endemic genus of a widespread subfamily, shares characters of two genera that each have a fossil record; if all three genera diverged from a common ancestor they separated in early Tertiary times. By analogy with other species of Hydrobiidae the local endemic species of *Mexipyrus* have evolved during the last 2 to 3 million years; if so, individual large springs or groups of springs have such antiquity.

Two of the species that do not belong to endemic genera are nonetheless remarkable. *Assimineae* spec. is a rare inland occurrence of a usually coastal, marine family. *Cochliopina milleri*, spec. nov., is related to species of northern Guatemala rather than geographically nearby forms.

The following new groups are known only from the valley of Cuatro Ciénegas:

Cochliopinae: *Cochliopina milleri*, spec. nov.; *Coahuilix hubbsi*, gen. et spec. nov.

Littoridininae: *Duragonella coahuilae*, spec. nov.; *Mexipyrus*, gen. nov., with *M. carranzae*, *M. churinceanus*, *M. escobadae*, *M. lugoi*, *M. mojarrales*, *M. multilineatus*, spp. nov.

Nymphophilinae, subfam. nov.: *Nymphophilus minckleyi*, gen. et spec. nov.

Hydrobiidae?

Mexithaumatinae, subfam. nov.: *Mexithauma quadripaludium*, gen. et spec. nov.

Paludiscalinae, subfam. nov.: *Paludiscala caramba*, gen. et spec. nov.

Appraisal of the fauna has required a substantial review of many groups, including the freshwater Rissoacea of the Western Hemisphere. All of the genera described as Hydrobiidae from North America have been allocated to a subfamily within that group, or have been referred to another family. The family Hydrobiidae, and all North American subfamilies within it, have been diagnosed. All of the South American genera that belong to one of these subfamilies have been so allocated; a few genera without northern relatives are ignored. All of the North American, and some South American forms of the Cochliopinae and Littoridininae have been listed by genera to clarify the geographic distribution of the groups. This taxonomic revision has led to the establishment of the following groups that are new in scope or definition but not always in name.

Hydrobiidae

Cochliopinae, subfam. nov., with three new tribes:

Cochliopini, Horatiini, and Clenchiellini

Fontigentinae, subfam. nov.

Lithoglyphinae, subfam. nov.

Littoridininae, subfam. nov.

In numerous attributes of several organ systems the Bithyniidae, generally classified in or near the Hydrobiidae, are radically different. They are transferred to the Viviparacea, and in so doing the value of the radula in indicating affinity among lower Mesogastropoda is sharply questioned.

The brackish-water genus *Clenchiella* ABBOTT, 1948, is classified among Cochliopinae in Hydrobiidae. It is significant in possessing low swellings on the posterior border of the left tentacle, a multispiral operculum with sub-central nucleus, and planispiral shell. This combination of features is found also among marine Vitrinellidae, and provides evidence that the marine family is derived from the Cochliopinae.

Comparison of the fauna from the valley of Cuatro Ciénegas with that of adjacent regions led to two compilations. One is the known fauna of Coahuila, consisting of five species so far as previously published records go. With additions from both inside and outside the Cuatro Ciénegas area this total is increased to 26.

A second compilation is literature on freshwater mollusks from northeastern México (states of Chihuahua, Nuevo Leon, San Luis Potosí, and Tamaulipas) published since the last summary in the "Biologia Centrali-Americana"; and on those from southern and western Texas, and from the Rio Grande drainage in New Mexico, U. S. A. The literature is widely scattered and probably some

has been overlooked, but it is still evident that little is known of this vast region.

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# A New Genus and Species of Buccinidae from the Fiji Islands

(Mollusca : Gastropoda)

BY

WALTER O. CERNOHORSKY

Vatukoula, Fiji Islands

(Plate 20; 3 Text figures)

RECENT COLLECTING in the Fiji Islands has brought to light living specimens of a buccinid species, which after comparison with related forms already known appears to be new to science. Study of the soft parts of this new species leads to the necessity of erecting a new genus which, according to our present knowledge, appears to be confined to the Pacific region.

## GASTROPODA

### Prosobranchia

#### BUCCINIDAE

*Sukunaia* CERNOHORSKY, gen. nov.

Type species: *Sukunaia jenningsi* CERNOHORSKY  
spec. nov.

**Description:** Shell spindleform, somewhat inflated, teleoconch of six convex and swollen whorls, protoconch of  $1\frac{1}{2}$  smooth nuclear whorls. Body whorl smooth, penultimate whorl obsoletely striate, antepenultimate whorl spirally corded, earlier whorls clathrate; sutures distinct but moderately shallow, body suture oriented obliquely to axis. Aperture wide, oval, edge of outer lip obsoletely denticulate, labrum with weak plicae; columella concave, with a blunt denticle anteriorly of columella and another sharply sculptured denticle on parietal wall. Anterior canal short, wide and open.

Radula with small trapezoidal rhachidians, which are equipped with only a few obsolete, irregular and slender denticles which generally do not protrude past the top of the plate; in only one juvenile specimen did the central cusp slightly overlap the edge of the plate. Laterals with 3 strong cusps, base of plate with a prominent knob facing rhachidians.

**Discussion:** In general outline and characters, shells of the new genus resemble *Appisania* THIELE, 1929; however, shells of the latter genus have less convex whorls which are prominently spirally corded, and the protoconch has generally  $2\frac{1}{2}$  nuclear whorls. The denticles on the edge of the labial lip are prominent and sharp, plicae on labrum well developed. The radulae and opercula, however, are appreciably different.

*Sukunaia jenningsi* CERNOHORSKY, spec. nov.

**Description:** Shell small, spindleform, spire longer than aperture; dark purple in colour, ornamented with 15 tan-coloured spiral lines on body whorl and 7 such lines on the penultimate whorl; an obsolete central transverse zone is indicated on the body whorl by nebulous bluish-white, transversely oriented spots, which are distributed over 4 tan spiral lines; nebulous and almost obsolete bluish-white narrow axial flames are positioned within the 4 light coloured spiral lines. Teleoconch of 5 whorls (1 whorl and protoconch missing), whorls regularly convex and swollen, body whorl concave near suture which is placed obliquely to the axis of the shell; body whorl smooth, with only superficial spiral ridges near suture, and spiral cords towards the base, penultimate whorl obsoletely spirally striate, antepenultimate whorl spirally corded, earlier whorls clathrate; sutures distinct but shallow. Aperture wide and oval, interior light blue to violet in colour, edge of labial lip with 14 dark purple, blunt and somewhat obsolete denticles, labrum with 17 weak plicae which extend towards interior of aperture, ultimate anterior plica short and prominent; columella anteriorly bluish-white, sculptured with a blunt and somewhat triangular denticle, columellar wall purplish-brown, parietal wall purple and with a prominent bluish-white denticle. Anterior canal short, wide and open, aperture flaring anteriorly.

**Range:** One immature specimen was complete (Paratype 3), and the teleoconch consisted of 6 whorls of which the first 3 whorls were clathrate; the protoconch consists of  $1\frac{1}{2}$  smooth, glassy, lavender-coloured nuclear whorls, with the first one-half turn being dark purple. The white axial

The dark purplish denticles at the edge of the labial lip number 16 and 17 in Paratypes No. 1 and No. 2 respectively.

The operculum is elliptical, slightly pointed anteriorly and posteriorly, nucleus terminal but obsolete defined. Operculum is light brown in colour, ornamented with 2 axially curved purplish-black zones, the one near the columellar margin the largest; only in one juvenile specimen (Paratype No. 3) did the 2 dark zones coalesce.

Periostracum although thin is moderately opaque in the dried state, and is yellowish-grey in colour.

**Animal:** Sole of foot creamy-white, dorsum of foot blackish-grey, ornamented with light-coloured encircling lines; siphon mottled with greyish-brown. Tentacles very short and stubby, rounded at distal end, eyes very small, black, and situated on the outer edge of the thickened base; proboscis light fawn coloured, long and slender, with a nipple-like protrusion at the distal end.

**Radula:** The radulae of the holotype and 4 paratypes were examined. The radular ribbon is translucent-white, but the last 20-odd fully formed rows of teeth are orange-brown, nascentes are white. Length of ribbons ranged from 11.5 mm to 15.3 mm, the width from 0.49 mm to 0.68 mm, in shells 19.7 mm to 23.2 mm in length. The ribbons contained 113 to 131 fully formed rows of teeth (+ 8 to 11 nascentes), and early rows of teeth displayed appreciable wear on cusps. Rhachidians are trapezoidal in outline, straight or very slightly convex at the base; cusps are almost obsolete, irregular and slender, and may vary in number in rhachidians of the same ribbon; the cusps generally do not protrude beyond the margin of the plate; however, in one ribbon examined the central cusp overlapped only slightly past the edge of the plate. Laterals larger than rhachidians, base of plate concave and with a prominent knob at end facing rhachidians; laterals are equipped with 3 massive curved cusps, of which the outer cusp is the longest, central cusp the smallest.

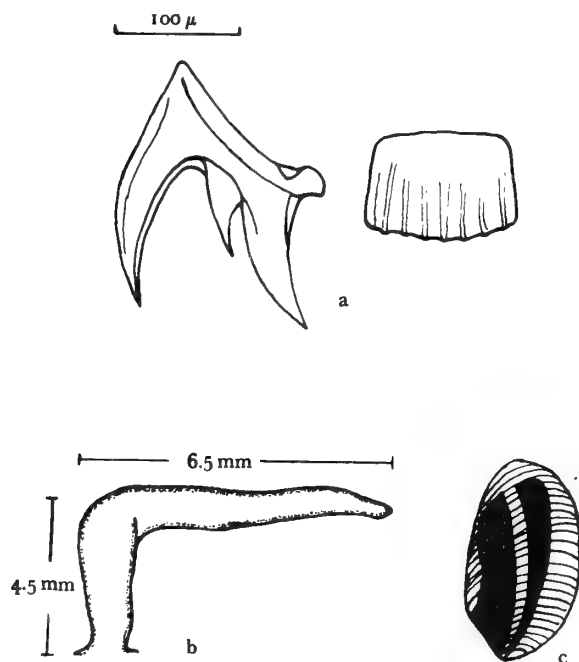


Figure 1

*Sukunaia jenningsi* CERNOHORSKY  
a: Half-Row of Radula      b: Penis  
c: Operculum (immature specimen)

flames on the body whorl are prominent in some specimens and may also be visible on the penultimate whorl.

## Explanation of Plate 20

Figure 1: *Sukunaia jenningsi* CERNOHORSKY. Holotype, Smithsonian Institution, U.S.N.M. No. 673301; 23.2 mm. Naevuevu, Viti Levu, Fiji (x 2.0)

Figure 2: *Sukunaia jenningsi* CERNOHORSKY. Paratype 1 (coll. A. Jennings); 23.1 mm. Naevuevu, Viti Levu, Fiji (x 1.9)

Figure 3: *Sukunaia jenningsi* CERNOHORSKY. Paratype 3 (immature), British Museum (Natural History) No. 1966194; 19.7 mm. Naevuevu, Viti Levu, Fiji (x 2.5)

Figure 4: *Sukunaia jenningsi* CERNOHORSKY. Paratype 4 (immature), coll. Cernohorsky; 22.8 mm. Naevuevu, Viti Levu, Fiji (x 1.9)

Figure 5: *Appisania montrouzieri* (CROSSE). Northwest Island, Queensland (x 2.4)

Figure 6: *Appisania montrouzieri* (CROSSE). Viti Levu Bay, Viti Levu, Fiji (x 2.1)

Figure 7: *Appisania montrouzieri* (CROSSE). Suva, Viti Levu, Fiji (x 1.9)

Figure 8: *Appisania montrouzieri* (CROSSE). Hazlewood Island, Whitsunday Group, Queensland (x 2.3)

Figure 9: *Appisania fasciculata* (REEVE). Davao, Mindanao, Philippine Islands (beach specimen; leg. Arnalot), U.S.N.M. No. 231048 (x 1.75)





Figure 1



Figure 2



Figure 3



Figure 4



Figure 5

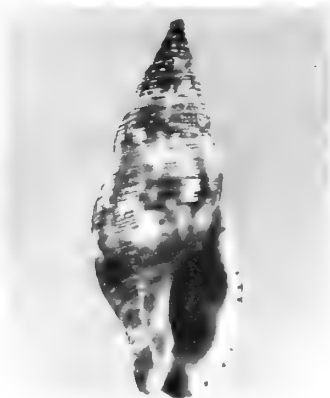


Figure 6



Figure 7

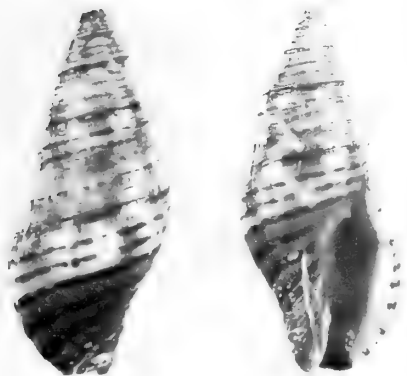


Figure 8

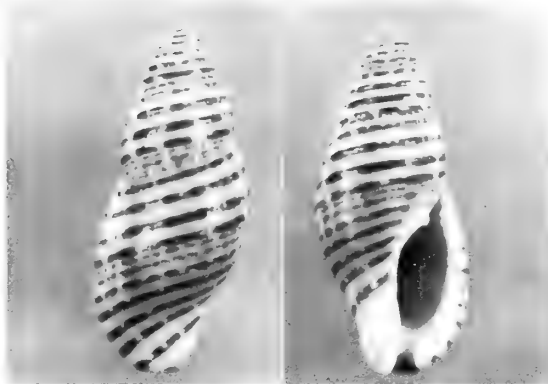


Figure 9



**Type Material:** Holotype – Height 23.2 mm; maximum diameter 10.4 mm; height of aperture 11.7 mm (apex missing). The holotype and radular ribbon have been deposited with the Smithsonian Institution, U. S. National Museum, Washington, where they bear the catalogue number U. S. N. M. 673301.

Paratype No. 1 – 23.1 x 10.5 x 11.6 mm (apex missing) and Paratype No. 2 – 21.2 x 10.3 x 11.5 mm (apex mis-

species *Buccinum ferreum* REEVE, 1847, from the Japanese region, and referred to COOKE's figure of the radula of this species (1917, p. 234, fig. 3). The genus *Pisania* BIVONA, 1832 (type species *Murex striata* GMELIN, 1791 – Mediterranean) appears to be conchologically related to *Japeuthria*; however, the radulae differ appreciably. THIELE (1929) established the section *Appisania*, with *A. montrouzieri* (CROSSE, 1862) as type species; the

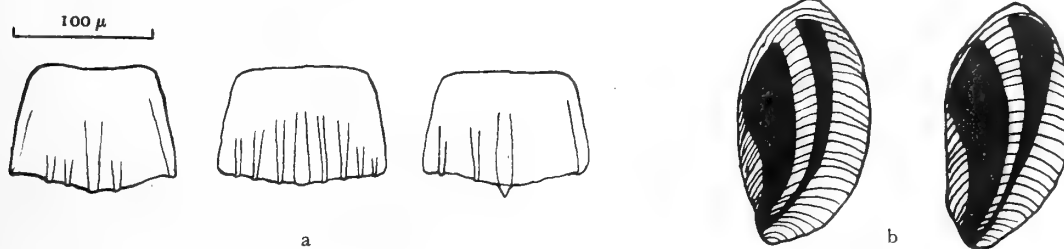


Figure 2

*Sukunaia jenningsi* CERNOHORSKY

a: Variation in Rhachidians of Radular Ribbons  
b: Opercula of Adult Specimens

sing) are in the collection of A. Jennings, Nadi Airport, Fiji.

Paratype No. 3 – 19.7 x 8.8 x 10.4 mm (immature), has been deposited with the British Museum (Natural History), where it bears the registration No. 1966194.

Paratype No. 4 – 22.8 x 10.6 x 12.0 mm (immature, apex missing), and the 4 radulae of all paratypes are in the author's collection.

All type material has been collected by A. Jennings, Nadi Airport, Fiji Islands.

**Type Locality:** Naevuevu, Southwest Viti Levu, Fiji Islands—Lat. 18° 09' 44" South and Long. 177° 26' 50" East. Specimens were collected on the Nadroga Reef, ½ mile southeast of Naevuevu village. They were obtained intertidally at low tide (25-IX-1965) by cracking solid coral about 7 to 8 yards from the reef-edge; the specimens were nestling in a depression within the coral. Age: Recent.

**Distribution:** At the present time the species is known from the Fiji-Samoan region. One specimen of *Sukunaia jenningsi* has been collected recently at Asau Harbour, Savai'i, Western Samoa, by R. Jameson (Dr. H. Rehder, *in litt.*).

**Discussion:** A number of buccinid genera must be taken into consideration in the discussion of the new genus. IREDALE (1918) established the genus *Japeuthria* for the

radula of this species is quite distinct from those of *Japeuthria* and *Pisania*. It is *Appisania montrouzieri* which resembles *Sukunaia jenningsi* in shell-characters, and reliable records of *A. montrouzieri* are from East Australia, New Caledonia and the Fiji Islands. The latter species is sculptured with 19 to 21 thin spiral ridges on the body whorl and 10 to 11 ridges on the penultimate whorl; the interstices of the main spiral ridges are sculptured with 4 to 5 intermediate fine spiral lirae. This feature which is absent in *S. jenningsi*, was observed in all specimens of *A. montrouzieri* from Queensland and Fiji. The general colour of *A. montrouzieri* is a dark fawn or brown, with dark brown spiral ridges and numerous white spots superimposed on almost every ridge. The denticles on the labial lip are smaller but sharper, white, and with only an occasional brown spot along the edge; the plicae on the labrum are quite prominent. The columella is a rich tan in colour, and the protoconch consists of 2 to 2½ glassy, brown and smooth nuclear whorls, with the first turn being milky-white; the aperture is narrower, elliptical and does not widen anteriorly.

The radulae of 6 specimens of *Appisania montrouzieri* from North-West Island, Queensland, Australia (*leg.* N. Hunter) were examined. The radula differs appreciably from that of *Sukunaia jenningsi*, rhachidians being equipped with 5 prominent cusps, and laterals bear a

huge massive inner cusp, a very small and occasionally hardly visible central cusp and a medium-sized outer cusp. The penis is chestnut-brown and only  $3.7 \pm 1.3$  mm long (after preservation) in a shell 23 mm in length. The operculum is fawn to light orange-brown in colour, with a terminal nucleus, but lacking the two dark axial zones of *S. jenningsi*.

*Appisania fasciculata* (REEVE, 1846), which is distributed from Mozambique to the Fiji Islands, also superficially resembles *Sukunaia jenningsi*. It has a yellowish orange base colour, and is ornamented with 12 to 15

Jennings, Nadi, who collected the type-material, and who through continuous field work has been responsible for new geographical records of mollusca from Fiji.

### ACKNOWLEDGMENTS

I would like to thank Dr. Harald Rehder, Smithsonian Institution, U. S. National Museum, Washington, for his assistance with references and other information, and comparison of the new species with molluscan material from other regions. The loan of molluscan material by

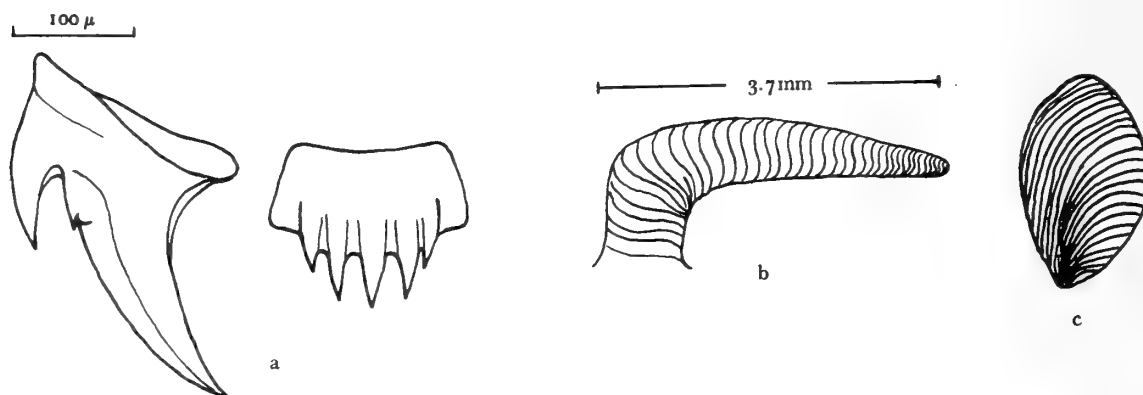


Figure 3

*Appisania montrouzieri* (CROSSE)

from Northwest Island, Queensland

a: Half-Row of Radula      b: Penis      c: Operculum

reddish-brown, wide-spaced and broader spiral ridges on the body whorl, and about 6 such ridges on the penultimate whorl; spiral ridges are dotted with white and interstices bear 3 to 4 fine spiral lirae. The sutures are so indistinct that the upper whorls appear continuous. Two specimens of *Appisania* collected at Hazlewood Island, Whitsunday Group, Queensland (*leg.* R. Carey), appeared to be intermediate in shell-characters between *A. fasciculata* and *A. montrouzieri*. Radulae of both specimens were examined and were found not to differ from those of *A. montrouzieri*; the opercula were almost identical. It is highly probable that *A. montrouzieri* and *A. fasciculata* are conspecific.

The new genus has been named in honour of the late Sir Ratu Lala Sukuna, a man of many virtues and accomplishments and one of the greatest leaders of the Fijian people. The species has been named for Mr. A.

the Smithsonian Institution has been greatly appreciated.

The material received from Mrs. R. Carey, Proserpine, Mrs. N. Hunter, Avoca Beach, Mr. A. Jennings, Nadi, and Mr. R.F. Browne, Nausori, is gratefully acknowledged.

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# Silicified Sand-Pipes belonging to *Chaceia* (?) (Pholadidae: Martesiinae) from the Late Miocene of California

BY

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(Plate 21)

## INTRODUCTION

A FEW HAND SPECIMENS with several silicified sand and mud-filled pholad burrows and a few silicified pholads were collected by NOMLAND & GESTER in 1916 from Upper Miocene strata in San Luis Obispo County, California. This locality (Univ. Calif. Mus. Paleo. locality A-3415), as described on the label accompanying the collection, is on the Frazer property, about one mile south-east of Huasna school house, near the west central part of Section 29, T.23S., R.15E., San Luis Obispo County, California. These burrows, commonly referred to as "sand-pipes" (see UOZUMI & FUJIE, 1956; MASUDA & TAKEZAWA, 1961; ITOGAWA, 1963) are mostly elongate, with a long, proximally tapering, sub-circular neck which merges rather smoothly into a bulbous distal portion (Plate 21; Figures 1, 6, 9). A few of the burrows, however, are small and rounded (Plate 21, Figures 3, 8), and lack the typical elongate neck of the former.

The sand-pipes originate in whitish-gray, fine-grained and tuffaceous silty sandstone, and penetrate the underlying hard, dull greenish-brown, siliceous and cherty mudstone of "Monterey type" (see BRAMLETTE, 1946). Because of the high silica content of the penetrated rocks (BRAMLETTE, *op. cit.*), the burrows, as well as their contents have been partially silicified, most of them having a dull, glassy appearance (Plate 21, Figures 1, 2, 4). In a few specimens, faint indications of the original occupant can still be discerned with some difficulty. These (Plate 21, Figures 4, 7, 8) have thin-walled, extremely short and bulbous valves, which probably fit rather loosely along the dorsal and ventral margins. There is also some indication of the presence of wide anterior and posterior gapes (see below, and Plate 21, Figures 7, 8). These

characters, especially the short bulbous valves preclude their inclusion with some common pholad genera such as *Pholadidea*, *Penitella*, and *Zirfaea* which are typically elongate; but they are highly suggestive of the genus *Chaceia* TURNER, 1955. As none of the specimens could be satisfactorily extracted from the matrix for detailed study no specific name is suggested for the pelecypods in this report.

## STRATIGRAPHY

The lithology and stratigraphic relationships of Late Miocene strata in the San Luis Obispo area are aptly and succinctly described by BRAMLETTE (1946, p. 6). In this region, the siliceous Monterey Formation is overlain by tuffaceous, whitish-gray sandstone beds of the Pismo Formation. The latter is generally regarded as a lateral equivalent of the Late Miocene Santa Margarita Formation (BRAMLETTE, 1946, p. 6; FAIRBANKS, 1904, p. 4).

The pholad burrows originate in the tuffaceous Pismo Formation, and project half to more than three inches down into the underlying hardened, greenish-brown, siliceous chert of the Monterey Formation (Plate 21, Figures 5, 8, 9). The disconformable relationship between these two lithologic entities is apparent from the largest figured specimen (Plate 21, Figure 9). Here, the proximal ends of all the sand-pipes are aligned along the irregular erosional contact of the fine-grained sandy Pismo Formation with the underlying Monterey chert. There is, however, no doubt that the initial ends of the sand-pipes originated in the overlying Pismo Formation. Furthermore, the burrows, though mostly enclosed in the hard cherty rocks, are completely filled with fine-grained, light gray, tuffaceous sediments similar in texture and composition to those of the Pismo sandstone. Thus, the organisms inhabiting them must have lived during the deposition of the latter.

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## SAND-PIPES

The sand-pipes examined fall into two gross morphologic types (Plate 21). All have a sub-circular cross-sectional outline. The majority of them are elongate, with a long neck through which the siphon was extended, and a short bulbous distal end in which the borer lived. A few burrows are small and spherical with no elongate neck (Plate 21, Figures 3, 8). Intermediate forms with short, slender necks (Plate 21, Figures 5, 9) complete the gradational morphological spectrum. Inasmuch as the observed variations in length of burrow coincide with a similar gradation in size, the small, spherical forms are here regarded as young individuals; the gradually increasing length of neck representing a continuous increase in siphonal length with age. The smallest sand-pipe observed is about 4 mm long, and the longest about 66 mm.

The mollusks fit snugly into their burrows and apparently have very little freedom of movement laterally. Such tight-fitting burrows are characteristic of species that burrow into hard substrates (TURNER, 1955). The disconformity between the Pismo Formation, in which the sand-pipes originate, and the underlying Monterey Formation into which they burrowed indicates that the Monterey sediments had been consolidated, and eroded before the area was invaded by the borers. In this, and in other similar studies of boring bivalves (UOZUMI & FUJIE, 1956; ADEGOKE, 1966), it is commonly found that a very large number of borers live and burrow side by side in small pockets (see Plate 21, Figures 5, 9).

Faint impressions of occupants are visible in a few of the silicified burrows (Plate 21, Figures 2 - 5, 7 - 8). In general, the short distal portion of the burrow occupied by the borer is hollow and thin-walled when well preserved. In one specimen (Plate 21, Figures 4, 7), the thin valves and the elongate-oval posterior gape are preserved. On one side of the same specimen (Plate 21, Figure

4), a faint, straight, shallow groove between the closed valves indicates that the valves probably fitted only loosely together in the living animal. A few specimens (Plate 21, Figures 2, 7) show faint indications of what might have been radial lamellar ribs. In all cases where remains of the original occupants are visible, the valves are characteristically short, with an oval outline, and a relatively small length/height ratio. Additionally, they appear to have been buried *in situ*, that is with the rounded anterior end pointing vertically downward and the siphonal end pointing upward. The numerous holes visible in the anterior region of the burrows (Plate 21, Figures 1 - 5) probably indicate presence of a weakened anterior region which is here interpreted as indicative of the presence of a wide anterior (pedal) gape, which is, at best, only partially closed by a callum.

## AFFINITIES

Because no well-preserved specimen could be extracted for study, the affinities of these fossils are not definitely known. However, the remarkably short body, spherical or ovoid outline, thin-walled valves, probable presence of pedal and siphonal gapes, and the faint lamellar ribs not unlike those of *Chaceia* (see TURNER, 1955), suggest probable affinities with that genus.

Another evidence suggestive of probable relationship between these fossils and *Chaceia* is the similarity in the habitat preferences of both. According to TURNER (1954), *Chaceia ovoidea* (GOULD, 1851), the only known species of the genus, lives in soft shale rock in association with *Penitella penita* (CONRAD, 1837), *P. gabbi* (TRYON, 1863), and *Parapholas californica* (CONRAD, 1837). The boring habits of most of these associated genera have been extensively studied by many earlier workers and were recently reviewed by YONGE (1951, 1951a) and TURNER (1954). All of them, especially *Penitella*, are capable of burrowing

## Explanation of Plate 21

Figures 1 to 9: Partially silicified sand-pipes created by *Chaceia* (?) sp. indet., from Univ. Calif. Mus. Palco. locality A-3415, San Luis Obispo County, California.

Figure 1: Hypotype, UCMP no. 32523,  $\times 1\frac{1}{2}$

Figure 2: Hypotype, UCMP no. 32522,  $\times 1\frac{1}{2}$

Figures 3 and 8: Hypotype, UCMP no. 31410,  $\times 1.9$ . Specimen showing two small, spherical, thin-walled and hollow burrows probably made by immature individuals.

Figures 4 and 7: Hypotype, UCMP no. 34092. Figure 4, specimen showing hollow distal end and faint, straight groove indicating contact of valves;  $\times 1\frac{1}{2}$ . Figure 7, top view of same specimen showing posterior margin of valves and partially exposed siphonal gape;  $\times 1.9$

Figure 5: Hypotype, UCMP no. 31409,  $\times 1\frac{1}{2}$ ; hand specimen showing several burrows existing side by side.

Figure 6: Hypotype, UCMP no. 15547;  $\times 1$

Figure 9: Hypotype, UCMP no. 12197;  $\times 1$ ; hand specimen showing numerous small and large-sized sand-pipes, and the disconformable relationship between the whitish-gray, fine-grained, tuffaceous sandstone of the Pismo Formation (in which sand-pipes originate) and the underlying hard, greenish-brown, siliceous and cherty mudstone of the Monterey Formation in which the sand-pipes are enclosed.

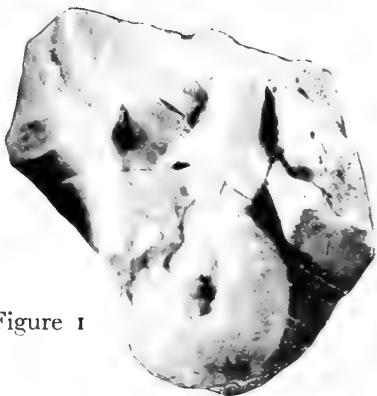


Figure 1



Figure 2



Figure 3

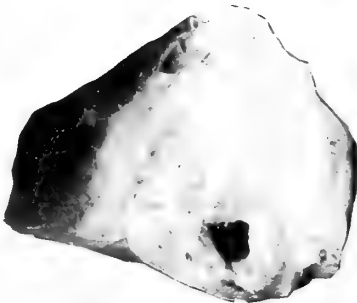


Figure 4

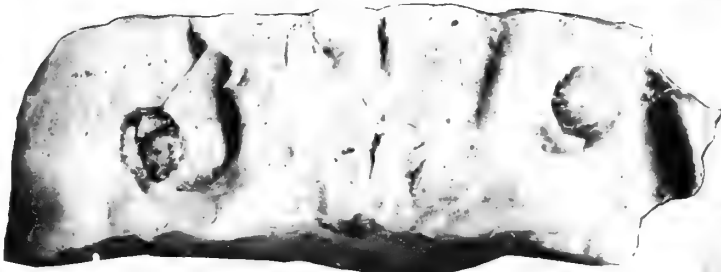


Figure 5



Figure 6



Figure 7

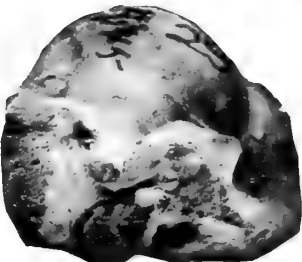


Figure 8

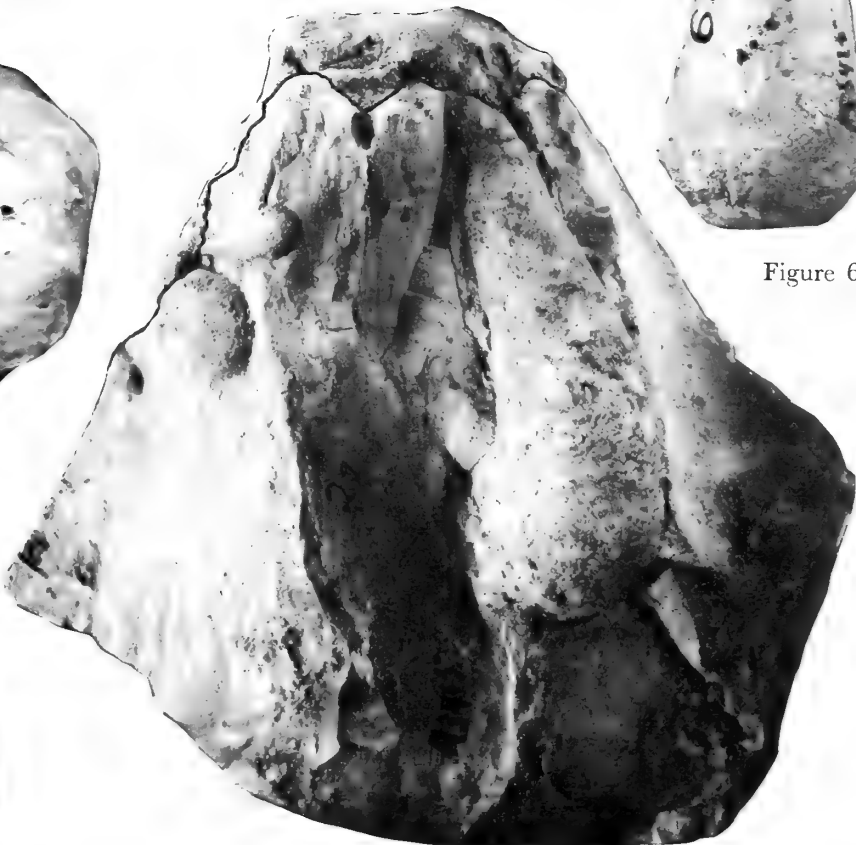


Figure 9





into extremely hard rocks and even into concrete (KOFOD & MILLER, 1923). The recorded occurrence of these fossil borers in hard siliceous and cherty rocks is thus in harmony with the known habit of modern representatives of the genus.

The present record of a probable species of the genus *Chaceia* from the Late Miocene of California is significant. The only known species of the genus, *C. ovoidea* (GOULD) is characterized by its "short ovoid form" (GRANT & GALE, 1931). In her recent review of the species, TURNER (1955) clearly stated that many other elongate Pacific Coast species correctly referable to *Penitella penita* (CONRAD) and *P. gabbii* (TRYON) had been wrongly assigned to this species by most earlier workers. Her account, however, contained only a few references to fossil occurrences of the species. She (1954, p. 16) agreed with GRANT & GALE (1931) in listing the species as ranging from ?Pliocene to Recent. The limit of the species as construed by the latter authors was too inclusive as both *Zirfaea crispata* (LINNAEUS, 1758) of NOMLAND (1917; Middle Pliocene, Etchegoin Formation) and *Z. gabbii* TRYON of GABB (1869, Pleistocene, San Pedro series) included in *C. ovoidea* by them are to be correctly assigned to *P. gabbii* (TRYON). Thus, presently known evidences would suggest that *C. ovoidea* (GOULD) is not indisputably known as fossil in beds older than Pleistocene.

The present record of the genus from the Late Miocene thus assumes greater importance especially with regard to phylogenetic and evolutionary considerations. The record, if further authenticated, suggests that ancestors of the genus *Chaceia* diverged from some presently unknown Middle or Late Miocene pholad stock. Specific determinations of the characters of this ancestral stock or of the Miocene representatives of the genus must await discovery of better preserved specimens.

## ACKNOWLEDGMENTS

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## Notes on the Mollusca of Prince William Sound, Alaska. Part II

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(Plate 22)

THIS IS A SECOND PAPER on the mollusks observed and collected during the summer of 1965, on and about Prince William Sound at the head of the Gulf of Alaska. As in the earlier discussion, I will stress the extension of published ranges, ecology, abundance or paucity of species rather than taxonomy. The names of taxa used will be those of DALL (1921), OLDROYD (1924-1927), and KEEN (1937), which are available in most libraries. Explanations, and citations to other authors will only be made where needed for clarification.

The following data have been listed under Orders and Families for convenience, and there is no doubt in our minds that other species may be found inhabiting the same region. Taxonomy will also probably be changed as more detailed studies are made.

## ARCHAEOGASTROPODA

## TROCHIDAE

*Calliostoma ligatum* (GOULD, 1849)

EYERDAM (1960) lists the species from the Kodiak group of islands, but did not record the species from Drier Bay (1924), Knight Island, Prince William Sound. We, too, failed to locate the species at Squirrel Island (Knight Island group) and at the mainland localities of Falls and Eshamy Bays on the Kenai Peninsula. However, shells of this species were common at localities along the Montague Passage, but all specimens were small, the largest measuring only 14 mm both in diameter and in height. All shells were highly colored, matching *Calliostoma ligatum pictum* DALL, 1919.

*Solariella peramabilis* CARPENTER, 1864

Scattered specimens were dredged between 5 and 25 fathoms at various localities along Montague Channel. This species can not be considered common based on the number of specimens taken by the two of us. This locality appears to represent a northern extension of the published range of the species.

*Solariella obscura* (COUTHOUY, 1838)

This small *Solariella* was the more common of the two species that were dredged, and although DALL (1921) does not list the species, both OLDROYD (1927) and KEEN (1937) give a distribution that would include Prince William Sound.

*Cidarina cidaris* (A. ADAMS in CARPENTER, 1864)

A few specimens were dredged between 17 and 25 fms., from a sandy-mud bottom. EYERDAM (1924) lists the species from this region.

The genus *Margarites* was well represented at Prince William Sound. Specimens were forwarded to Dr. James H. McLean of the Los Angeles County Museum, a specialist in this genus, for examination. The names used herein are those used in the collections of the Los Angeles County Museum.

*Margarites pupillus* (GOULD, 1849)

This was perhaps the most common species of the genus and could be collected at all suitable localities. It is well within the known range of the species.

*Margarites rhodia* DALL, 1920

EYERDAM (1924) does not refer to this species, and KEEN (1937) places the species at only 55° North Latitude; we found it in deeper waters, sympatric with *Margarites pupillus*. It is possible that shells referable to *M. rhodia* may turn up in other sets of the more common *M. pupillus*.

*Margarites* sp.

A single example of an unknown, rather coarsely corded, shell was found in the collection. Reference is made here to this specimen, not for taxonomic purposes but rather to stress the abundance of species in the region.

*Margarites helacinus* (PHIPPS, 1774)

Specimens of these smooth pink shells were probably the second most commonly encountered in the area; they were found both on algae and on rocky faces sheltered by algae.

*Margarites beringensis* E. A. SMITH, 1899

Smooth brown specimens were identified by Dr. McLean as belonging to this species. We observed and collected them in small numbers; perhaps the largest numbers were picked off algae which came up with a fouled anchor at Port Chalmers, Montague Island. Baxter has recorded the species several times, but always only in small numbers.

*Lirularia parcipicta* (CARPENTER, 1864)

This small species was not uncommon but appears to have been missed by previous workers.

*Lirularia succincta* (CARPENTER, 1864)

This species, as *Lirularia parcipicta*, was taken from under rocks; a search in the available literature indicated that both of these two small species had previously been recorded only from Sitka. Prince William Sound is about five degrees of Latitude north of Sitka.

## NEOGASTROPODA

## CANCELLARIIDAE

Three species belonging to this family were taken in Prince William Sound by dredging. If we accept the information in the literature, two additional species may be found; and one of the three species collected might be divided into three subspecies. To me a subspecies is a distinct geographic entity and the idea of overlapping distribution of subspecies is unacceptable. However, this is not a taxonomic discussion, and as the descriptions of the subspecies are, to me at least, not sufficiently clear, I will use only nominate names. Few living specimens were obtained by dredging, and our results indicate that the family is not common in this region.

*Cancellaria circumcincta* DALL, 1873

A few living and a few dead examples were dredged off Port Chalmers, Montague Island from a mud bottom in 17 fathoms.

*Cancellaria modesta* CARPENTER, 1865

Only a few specimens were taken in association with *Cancellaria circumcincta* at Port Chalmers, and a few were obtained in 25 fathoms off Woodcock Point, Montague Island.

*Admete couthouyi* JAY, 1839

One living and a few dead specimens were dredged off Woodcock Point, Montague Island, in 25 fathoms, on a mixed bottom of sand, shell, and broken bryozoa. According to the literature, there are supposed to be three sub-

species or geographical races, all three of which are to be found in Prince William Sound. The material that we dredged and additional material in the Baxter collection did not reveal any noticeable difference in the shells; thus, only the nominate species is reported here.

## MURICIDAE

*Ceratostoma foliatum* (GMELIN, 1791)

A token set of specimens of this species was collected, as this animal was very common in the proper ecological situations over much of Prince William Sound. The northern limit of the range of this species, according to literature, is Sitka, Alaska, and the present locality is much farther north, thus extending the range considerably.

*Ocenebra interfossa* (CARPENTER, 1864)

EYERDAM (1924) referred to a single specimen of this species, dredged at Drier Bay, Knight Island, Prince William Sound. We took specimens in small numbers living on an intertidal rocky reef at the entrance to Stockdale Harbor on Montague Island. The specimens that we collected were an ashy grey, more pallid than specimens I had observed and collected at more southern stations.

*Ocenebra lurida* (MIDDENDORFF, 1848)

Middleton Island appears to be the northern-most recorded locality for this species in literature. We collected a few living examples in association with *Ocenebra interfossa* on the exposed barrier reef at Stockdale Harbor.

*Trophonopsis tenuisculpta* (CARPENTER, 1866)

A few living specimens were taken on the intertidal reefs at both Stockdale Harbor and Woodcock Point. This species is nearly as common as *Boreotrophon multicostatus*.

*Boreotrophon multicostatus* (ESCHSCHOLTZ, 1829)

(Plate 22, Figure 2)

This species was quite common in suitable ecological sites. Our collecting area is well within the range of the species.

*Boreotrophon pacificus* (DALL, 1902)

(Plate 22, Figure 1)

Specimens dredged in Prince William Sound seem to be referable to this species. All were very similar, with a long canal and with 18 to 20 varices. The species is uncommon in the Sound, and only one living example was dredged.

*Boreotrophon stuarti* (E. A. SMITH, 1880)

All of the specimens obtained were collected between McLeod and Hanning Bays on Montague Island. Most

of the shells were extricated from crevices which in pre-earthquake times had been situated in the deep intertidal or shallow subtidal levels. A few living examples were collected from the deep intertidal levels of this rocky reef.

*Thais lamellosa* (GMELIN, 1791)

Although the species was abundant throughout the area, only two token sets were taken, representing the two basic formations of the shell in this region. The populations of Hinchinbrook, Green, Channel, and Montague Islands were so similar as to be referred to as a single "Morph." All specimens were thick, the spire medium in height, and the sculpturing rather coarse, with dull coloration on most specimens. In contrast, the shells taken at Squirrel Island (Knight Island group), and a set available from Drier Bay on Knight Island were very distinct. These had an extremely tall spire, were finely and sharply sculptured, and were in most cases white in color.

*Thais lima* (GMELIN, 1791)

(Plate 22, Figure 8)

Two color phases were noted in this species. Hawkins, Hinchinbrook, and Montague Island specimens were all dull with a purple interior. Specimens from Squirrel and Knight Islands, as well as from mainland localities on the Kenai Peninsula (west side of the Sound), were white with a yellowish aperture. This was the only difference observed in the species over the region of the Sound.

*Thais emarginata* (DESHAYES, 1839)

Only dead shells were found on the elevated rocky shore line at Woodcock Point, Montague Island. Baxter had taken the species from several additional localities, prior to the earthquake, usually from more exposed sections of the coastline. The species appears to be less common in this region than in more southern localities. All of the specimens had the rather tall apex and the spindle-shaped whorls of DALL's *Thais emarginata projecta*.

*Thais canaliculata* (DUCLOS, 1832)

One specimen was picked up by Baxter on the elevated reef at Woodcock Point on Montague Island. The habitat evidently was rather limited even in pre-earthquake time, as the reefs were covered chiefly with serpulid worms and a leafy bryozoan, rather than the barnacle-mussel association. The species is reputed to be more abundant on the exposed or seaward side of the Sound.

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1927. The marine shells of the west coast of North America. Stanford Univ. Publ., Geol. Sci. 2 (3): 1 - 339; pls. 73 - 108
- Figure 1: *Boreotrophon pacificus* (DALL, 1902). Woodcock Point, McLeod Bay, Montague Island  
Figure 2: *Boreotrophon multicostatus* (ESCHSCHOLTZ, 1829). Woodcock Point, McLeod Bay, Montague Island  
Figure 3: *Opalia wroblewskyi* (MÖRCH, 1786). (see The Veliger, vol. 9, no. 1, p. 85)  
Figure 4: *Epitonium* cf. *E. caamanoi* DALL & BARTSCH, 1910. (see The Veliger, vol. 9, no. 1, p. 85)  
Figure 5: *Puncturella multistriata* DALL, 1914. (see The Veliger, vol. 9, no. 1, p. 83)  
Figure 6: *Puncturella cucullata* (GOULD, 1846). (see The Veliger, vol. 9, no. 1, p. 83)  
Figure 7: *Lepeta* sp. (see The Veliger, vol. 9, no. 1, p. 84)  
Figure 8: *Thais lima* (GMELIN, 1791). The two specimens on the left are from Squirrel Island, Knight Island Group; the two on the right are from Boswell Bay, Hinchinbrook Island.

## Explanation of Plate 22

- Figure 1: *Boreotrophon pacificus* (DALL, 1902). Woodcock Point, McLeod Bay, Montague Island  
Figure 2: *Boreotrophon multicostatus* (ESCHSCHOLTZ, 1829). Woodcock Point, McLeod Bay, Montague Island  
Figure 3: *Opalia wroblewskyi* (MÖRCH, 1786). (see The Veliger, vol. 9, no. 1, p. 85)  
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Figure 6: *Puncturella cucullata* (GOULD, 1846). (see The Veliger, vol. 9, no. 1, p. 83)  
Figure 7: *Lepeta* sp. (see The Veliger, vol. 9, no. 1, p. 84)  
Figure 8: *Thais lima* (GMELIN, 1791). The two specimens on the left are from Squirrel Island, Knight Island Group; the two on the right are from Boswell Bay, Hinchinbrook Island.

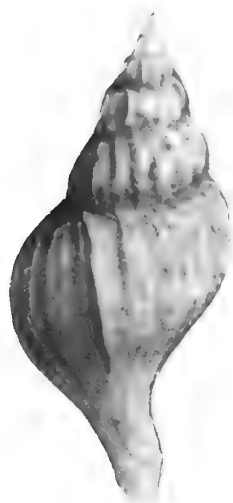


Figure 1



Figure 2

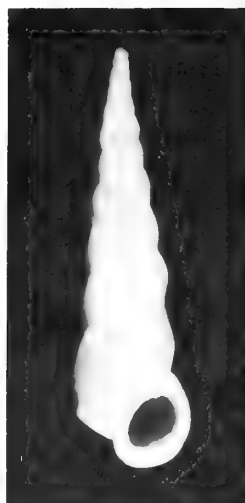


Figure 3



Figure 4

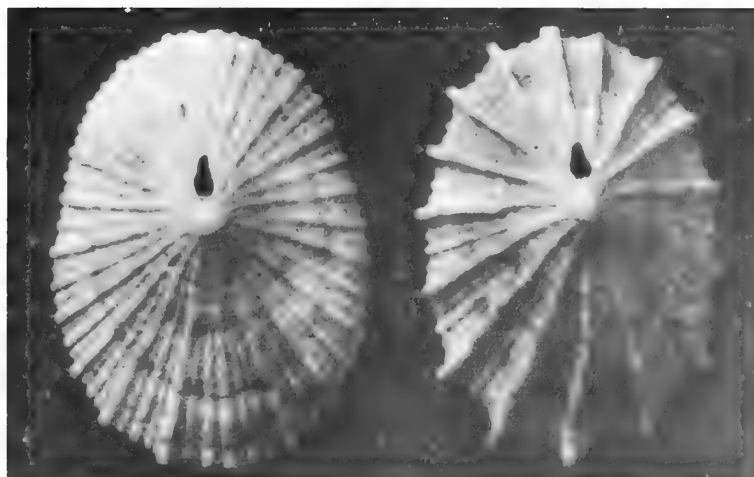


Figure 5



Figure 6

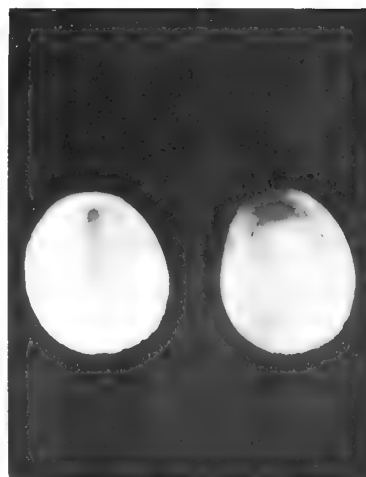


Figure 7

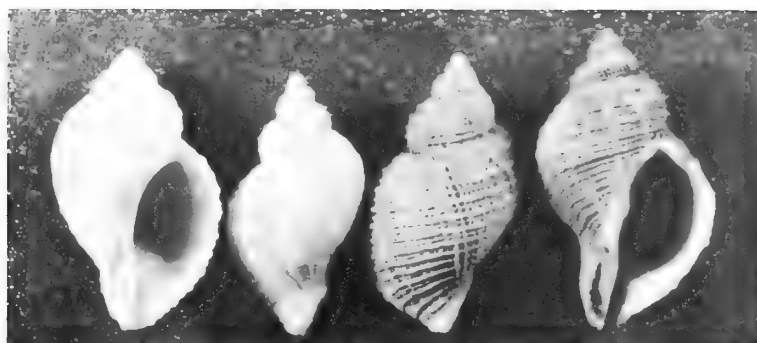


Figure 8



# A New Name for *Mitra sanguinolenta* LAMARCK, 1811

BY

JEAN M. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 23)

FROM NEWLY-COLLECTED SPECIMENS, it has recently been my privilege to identify a mitrid form that has evidently been considered a lost species for many years. Described as *Mitra sanguinolenta* by LAMARCK in 1811 without accurate illustration or definite locality, it was later figured or discussed variously by KIENER (1839), KÜSTER (1841), DESHAYES (1844), REEVE (1844), SOWERBY (1874) and TRYON (1882). Of the five illustrations in these six works, only those of KIENER and SOWERBY depict the shell now known to be the holotype of *M. sanguinolenta*; the others represent *M. nubila* (GMELIN, 1791).

The strong doubts about the species' validity through the years may be seen in such remarks as those made by REEVE: "Lamarck's *Mitra sanguinolenta* appears to be a variety of this species [*M. versicolor* MARTYN: = *M. nubila* (GMELIN)], and not the shell figured for it by Kiener, which looks like a worn *M. texturata*"; by SOWERBY: "Considered doubtful as figured by Kiener and here copied"; and by TRYON: "This species is known to conchologists only through the type figured by Kiener; Lamarck himself, according to his synonymy, appears to have confounded it with *M. versicolor*" [= *M. nubila*].

Aside from the rarity of the species, two other very evident reasons for so much confusion appear as soon as one glances over the pertinent literature. The first problem is an error of semantics, relating to the supposed type locality of the species. LAMARCK originally stated: "Habite . . . probablement l'Océan austral." This should be translated literally as "South Sea," but subsequent authors corrupted this citation variously until it evolved into "Australian Sea" — which has no meaning for malacologists in any possible interpretation.

The second and more serious problem besetting this attractive species is the fact that LAMARCK unaccountably referred to CHEMNITZ' figure of *Voluta nubila* GMELIN, 1791 as the type figure of *Mitra sanguinolenta*, thus invalidly describing his new species as a synonym of an already-established form. Even though it seems probable that this erroneous citation of a type figure was only a printer's

error (the species immediately preceding *M. sanguinolenta* in LAMARCK's list of 80 new species [*M. versicolor*] also has *Voluta nubila* as its type figure), nevertheless the species Lamarck intended to describe as *M. sanguinolenta* has been without standing for more than 150 years — not because the error was undetected, but probably because the species was rare enough that no worker has been sufficiently motivated to straighten out the synonymy.

Early in 1964, Mrs. Orville Davis of Orlando, Florida obtained from beach boys at Mogadiscio, Somalia (presumably gleaned from dredge-tailings when the harbor was de-silted) four specimens of a mitrid that she could not identify. Two of these were sent to the American Museum of Natural History in New York, and were eventually forwarded to me for identification. A third specimen is said to be at the Academy of Natural Sciences of Philadelphia, and the fourth was lost. Of the two shells sent to me for study, the smaller shell (Plate 23, Figures 1 and 2) seems to be almost an exact duplicate of the LAMARCK holotype of *Mitra sanguinolenta* presently in the collection of the Muséum Nationale d'Histoire Naturelle, Paris (see Plate 23, Figure 3). The larger of the Somalia specimens (Plate 23, Figures 4 and 5) may represent an older, worn example of the same species, though its sculpture is entirely smooth, several early whorls are lacking, and the shape of the aperture seems slightly different.

According to Article 11 (d) of the International Code of Zoological Nomenclature, a name published as a synonym is not available, and a new one should be provided. Therefore I propose the name

## *Mitra prosanguinolenta* J. CATE

*nom. nov. pro Mitra sanguinolenta* LAMARCK, 1811

(see Plate 23, Figures 1 to 5)

1811. *M. sanguinolenta* LAMARCK, Ann. Mus. d'Hist. Nat., *Mitra*, p. 200, no. 9 (not figured)

1839. *M. sanguinolenta* LAMARCK, KIENER, Icon. Coq. Viv., *Mitra*, p. 19, pl. 14, no. 45

1841. [non] *M. sanguinolenta* KÜSTER, Neues Syst. Conchylien-Cab., Volutacea, p. 88, pl. 27, figs. 6 & 7  
 1844. *M. sanguinolenta* LAMARCK, DESHAYES, Anim. s. vert., ed. II, p. 305 (not figured)  
 1844. [non] *M. sanguinolenta* REEVE, Conch. Icon., pl. 1, figs. 2 & 3  
 1874. *M. sanguinolenta* LAMARCK, SOWERBY, Thes. Conch. 4, pl. 11, fig. 160  
 1882. [non] *M. sanguinolenta* TRYON, Man. Conch. 5, p. 113, pl. 33, fig. 15  
 1962. *M. sanguinolenta* LAMARCK, J. CATE, The Veliger 5 (2), pl. 11, fig. 2 only  
 1965. *M. sanguinolenta* LAMARCK, CERNOHORSKY, The Veliger 8 (2), p. 92 (not figured)

"*M. Ovato-fusiformis, alba, maculis flammulisque sanguineis picta; sulcis transversis excavato-punctatis; columellâ quinqueplicatâ.*

"Mus., No. 9.

"Habite . . . probablement l'Océan austral. Cette mitre, dont le Muséum possède un exemplaire, mais plus petit que celui de Chemniz, est fort différente de l'espèce qui précède [*M. versicolor* LAMARCK = *M. nubila* (GMELIN)]: elle est blanche et ornée de taches et de petite flammes longitudinales d'un rouge éclatant, qui la rendent comme sanguinolente. Sa superficie offre des sillons transverses munis de gros points enfoncés, et des rides ou très-petites côtes longitudinales, qui la font paroître un peu granuleuse. Cette espèce est fort jolie et très-rare. L'exemplaire du Muséum n'a que 33 millimètres de longueur."

It seems appropriate to designate a tentative type locality, at least until additional material is discovered; tentative, first, because the specimens recently collected were not living at the time, and second, because the Somalia area may not be indicative of the species' entire living range, but possibly of one end of it only. It is hoped that publication of these illustrations will bring to light further similar specimens from additional localities. Until such time, however, I hereby designate as type locality for

*Mitra prosanguinolenta* the harbor at Mogadiscio, Somalia, East Africa (2° 00' N. Lat., 45° 17' E. Long.).

It should be noted that the two specimens collected by Mrs. Davis are both beige-white in color, overlaid with a striking rust-red network of lines which are incised and punctate in the smaller specimen. The smaller shell more closely resembles the holotype because of the above-mentioned surface ornament, the presence of a white band around the periphery of the shell, and a shorter and more constricted aperture; it is possible that two different species are involved here, but there is no question that specimen 1, the AMNH shell, is the *Mitra sanguinolenta* of LAMARCK. The larger shell may be merely an older, slightly worn example.

Aside from REEVE's statement that KIENER's figure looked "like a worn *M. texturata*," (*Mitra prosanguinolenta* is less obese than *M. texturata* LAMARCK, 1811, with smoother sculpture and a more produced spire), the only species with which *M. prosanguinolenta* may be readily compared is *M. puncticulata* LAMARCK, 1811; it is similar only in the suggestion of very slightly coronated sutures which are strongly developed in *M. puncticulata*, and in the surface ornament and pattern arrangement. However, in *M. prosanguinolenta* the outer lip is smooth and slightly effuse at the base, whereas *M. puncticulata* has a weakly crenulated lip and a straighter, relatively longer aperture. *Mitra prosanguinolenta* is brick-red and white, whereas *M. puncticulata* is predominantly orange, black, beige and white. Lamarck evidently also considered the two species perfectly distinct, for both were described as new species in the same paper without reference to the other.

Because the systematic arrangement of the Mitridae is presently undergoing revision, I have purposely not assigned *Mitra prosanguinolenta* to any subgenus, pending further investigation and a radular study of fresh material. Based on shell characters only, however, it seems to belong in *Mitra s. s.*

I wish to thank Mr. William Old and Mr. Anthony D'Attilio of the American Museum of Natural History

Statistics for the Specimens collected by Mrs. Davis are as follows:

	Specimen 1	Specimen 2
Illustrated on Plate 23	Figures 1 & 2	Figures 4 & 5
Length of shell	19.9 mm	35.4 mm
Greatest diameter	8.1 mm	13.1 mm
Length of aperture	11.5 mm	22.4 mm
Number of whorls	5, + 1½ nuclear whorls	4; apex missing
Present location	Am. Mus. Nat. Hist.	Coll. Mrs. O. Davis





Figure 1



Figure 2

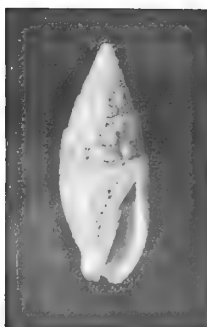


Figure 3



Figure 4

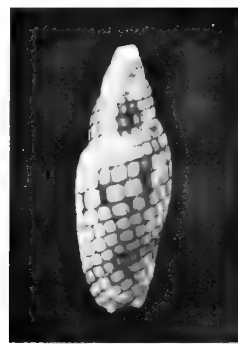


Figure 5

*Mitra prosanguinolenta* J. CATE,  
*nom. nov. pro Mitra sanguinolenta* LAMARCK, 1811

Figure 1: Ventral aspect of Specimen No. 1 (AMNH specimen) x 2

Figure 2: Dorsal aspect of the same shell x 2

Figure 3: Holotype of *Mitra sanguinolenta* LAMARCK

Photograph courtesy of and © by Nat. Mus. d'Hist. Nat., Paris x 1

Figure 4: Ventral aspect of Specimen No. 2 (Davis specimen) x 1

Figure 5: Dorsal aspect of the same shell x 1

(Except as noted, photographs are by Takeo Susuki)



for giving me the opportunity to work on this exciting find, the American Museum of Natural History for allowing me to publish my findings on the specimens in their care, and Mrs. Orville Davis for providing additional background information about her acquisition of the shells. I am indebted to Dr. Rudolf Stohler for suggesting the very apt name for the species, which fulfills the ICZN requirements without obscuring the original appropriate name given by LAMARCK.

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#### KIENER, LOUIS CHARLES

- 1839-1841. *Spécies général et iconographie des coquilles vivantes; Mitra et Voluta*. Rousseau, Paris 3: 1-120; pls. 1-34

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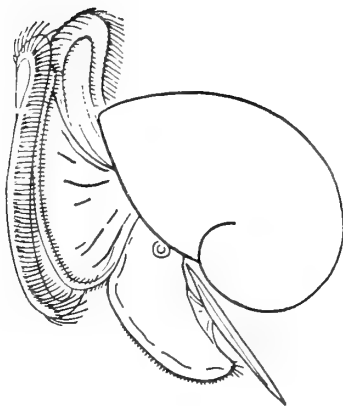
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#### SOWERBY, GEORGE BRETTINGHAM

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#### TRYON, GEORGE WASHINGTON, JR.

1882. *Manual of Conchology*. Monograph of the Mitridae. 4: 106-200; pls. 32-58. Philadelphia.



# The Geotactic Responses of the Land Snail *Helix aspersa* MÜLLER to a Reverse Incline

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(1 Text figure; 2 Tables)

## INTRODUCTION

SEVERAL AUTHORS OF GENERAL WORKS on animal behavior and orientation mention research on the geotactic response of various species of terrestrial gastropod mollusks. The species most commonly referred to seem to exhibit a negative taxis against gravity. The pulmonate, *Helix*, was reported to be strongly negatively geotactic, especially when submerged in water (FRAENKEL & GUNN, 1961). The tree snail, *Liguus*, was observed also to be strongly negatively geotactic to steep angles where the shell of the snail was pulled from its normal position (CARTHY, 1958).

In a recent paper on the orientation of *Helix aspersa* MÜLLER, 1774 (BOWER, 1962), results indicated that this snail was very sensitive to a slight angle of only 15 degrees. The degree of accuracy of the snail's negative geotactic orientation remained fairly constant as the angle of inclination was increased in steps from the horizontal to 90 degrees.

It would be of considerable interest, particularly from the point of view of an orientation mechanism within the snail, to extend the experiment performed by BOWER to include angles of more than 90 degrees. Thus, to exhibit their negative geotactic response, the snails would have to climb an incline upside down. This would place the snail's shell and statoliths in a different position, with relation to the body, than on a standard incline.

## METHODS

The same general methods as described by BOWER (1962) were followed. An adjustable inclined plane was constructed so that any desired angle of inclination could be achieved. Large sheets of art paper were fixed to the incline. The snails (*Helix aspersa*) were allowed to adhere

to the paper facing in various directions while the plane was set at  $180^\circ$  (horizontal). A thin ring of sodium fluorescein (water soluble uranine) was placed around the snails to provide a visible trail as they moved. The plane was then set in the desired incline. Ten snails were used for each trial so that traffic on the incline would not be

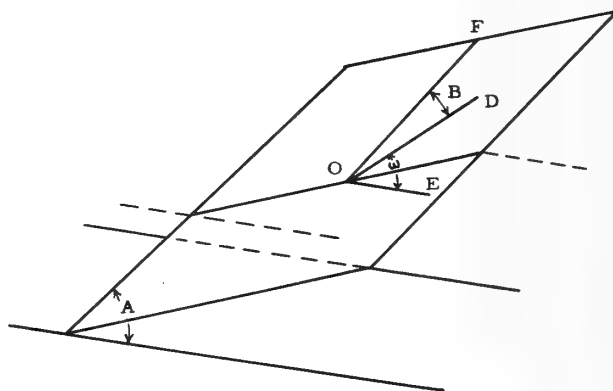


Figure 1

Reverse Incline Apparatus modified from BOWER<sup>3</sup> (1962)

A = Angle of inclination

B = Angle deviation (mean for group)

 $\omega$  = Angle between the snail's true path of orientation and the horizontal

O - D = Path of snail

O - E = Path of snail projected onto horizontal surface

O - F = Line of the surface perpendicular to the horizontal when the surface incline is  $90^\circ$

congested. After each trial the paper runway was replaced. Two trials at each angle were conducted on different days in total darkness, and the results were averaged. Each group of snails was given 15 minutes to move 10 cm. This was found to be adequate time for most. Those not moving the required distance were eliminated from the experiment. The angle of deviation from an expected straight line path up the incline was figured for each snail completing a 10 cm move. These angles were then averaged and used as an index of the snail's ability to respond to a given angle of inclination. Geotactic accuracy was calculated using the same methods as described by BOWER (Figure 1). Geotactic accuracy was determined by the equation:

$A - \omega$  = degree of accuracy

$A$  = the angle of inclination of the surface

$\omega$  = the angle between the snail's true orientation path and the horizontal.  $\omega$ , in turn, was derived by the equation:  $\sin \omega = \sin A \cos B$ , where  $B$  is the mean of the angular deviations.

## RESULTS

The results of BOWER's work with a standard incline are shown in Table I. Table II shows the results using a reverse incline.

Table 1

Summary of the Results of BOWER (1962) Showing the Degree of Accuracy of *Helix aspersa* to a Normal Incline

(A)	MAD	RAD	$\omega$	(A - $\omega$ )
0°	Control - Apparent Random Manner			
15°	28° 56'	1 - 57°	13° 10'	1° 50'
30°	20° 56'	1 - 51°	27° 50'	2° 10'
45°	15° 38'	1 - 30°	42° 55'	2° 05'
60°	11° 45'	1 - 27°	57° 59'	2° 01'
75°	7° 41'	1 - 17°	73° 08'	1° 52'
90°	8° 53'	0 - 39°	81° 07'	8° 53'

$A$  = angle of inclination

$\omega$  = angle between the snail's true orientation path and the horizontal

$A - \omega$  = degree of accuracy

MAD = mean of angle deviation

RAD = range of angle deviation

Table 2

Results of a Reverse Angular Inclination Where the Snails Must Climb the Incline Upside Down  
(See explanation in Table I)

(A)	MAD	RAD	$\omega$	(A - $\omega$ )
0°	Control - Apparently Unoriented			
15°	15° 54'	2 - 33°	14° 25'	0° 35'
30°	6° 48'	1 - 16°	29° 46'	0° 14'
45°	14° 12'	2 - 30°	43° 16'	1° 44'
60°	7° 28'	2 - 12°	59° 10'	0° 50'
75°	5° 42'	0 - 20°	74° 10'	0° 50'
90°	4° 12'	0 - 8°	85° 48'	4° 12'

## DISCUSSION

A comparison between Table I and Table II shows a similar degree of accuracy in the geotactic orientation of *Helix aspersa*. The data presented indicate that the accuracy of negative geotactic response of this snail is similar whether it is climbing an incline in an upright position or in a reversed, upside-down position. The discrepancies in the tables are most likely a result of the difficulties in accurate angle measurement of the groups of smaller sizes used in this experiment. These discrepancies, however, are slight. Also of some interest might be the small percentage of snails that did not move the required distance in the prescribed time. These snails were eliminated and their movement was not recorded. In each group one or two snails failed to show any response, but it is unlikely that these individuals would affect the data presented.

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# Material Contained in the Molluscan Type Collection of the Santa Barbara Museum of Natural History

BY

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SHORTLY AFTER the 1962 fire at the Santa Barbara Museum of Natural History, Santa Barbara, California, I published a list of destroyed type material (SPHON, 1962). Since that time, the Invertebrate Department has been housed in a new fireproof laboratory building with a separate locked room for type material.

The following is a list of the types acquired since 1962. As a rule only holotypes, paratypes, and other primary types are kept separate. Occasionally, hypotypes (any listed or figured specimens) are kept in the type room. This is done especially if the hypotype is part of the author's original material, a figured specimen, or cited in a major publication as a range extension.

## HOLOTYPE

- Lima (Plicacesta) sphoni* HERTLEIN, 1963  
Occ. Pap. Calif. Acad. Sci. no. 40, 6 pp., 3 figs.; 10 July 1963. SBMNH no. 03183
- Pyrene aureola* HOWARD, 1963  
Santa Barbara Museum Occ. Pap. no. 7, 12 pp., 2 pls., 3 tables; May 1963. SBMNH no. 10876
- Pterynotus (Pterochelus) phillipsi* E. H. VOKES, 1966  
The Veliger vol. 8, no. 3, pp. 165-166, plt. 25; 1 January 1966. SBMNH no. 22190
- Pterotyphis (Tripterotyphis) fayae* KEEN & CAMPBELL, 1964  
The Veliger vol. 7, no. 1, pp. 54-56, plt. 11, figs. 39, 40, 43 and 44, text figs. 1 and 2; 1 July 1964. SBMNH no. 15999
- Terebra (Strioterebrum) churea* CAMPBELL, 1964  
The Veliger vol. 6, no. 3, pp. 134-135, plt. 17, figs. 17, 18, and 24; 1 January 1964. SBMNH no. 03461
- Venus fordi* L. G. YATES, 1890  
Santa Barbara Soc. Nat. Hist. Bull. no. 2, p. 46, plt. 1, figs. 1-5; August 1890. SBMNH no. 22900

## PARATYPES

### AND OTHER PRIMARY TYPE MATERIAL

- Acmaea turveri fayae* HERTLEIN, 1958  
1 specimen, paratype no. 2
- Anculosa tryoni* LEWIS, 1870  
6 specimens, paratypes
- Berthelinia chloris belvederica* KEEN & SMITH, 1961  
1 specimen, paratype
- Cardita redondoensis* T. BURCH, 1944  
1 specimen, paratype
- Cerion caicosense* CLENCH, 1937  
1 specimen, paratype
- Cerion russelli* CLENCH, 1938  
1 specimen, paratype
- Chondropoma cleti* AGUAYO, 1939  
1 specimen, paratype
- Chondropoma yucayum bermudezi* A. TORRE & C. SANCHEZ, 1954  
1 specimen, paratype
- Cingula eyerdami* WILLET, 1934  
9 specimens, paratypes
- Clathrodrillia (Carinodrillia) bicarinata* SHASKY, 1961  
1 specimen, paratype
- Cyclostoma (Omphalotropis) roseum* GOULD, 1847  
3 specimens, paratypes
- Cypraea cernica viridicolor* C. CATE, 1962  
1 specimen, paratype
- Epiphragmophora californiensis miwoka* BARTSCH, 1919  
4 specimens, paratypes
- Epitonium tinctum bormanni* STRONG, 1941  
4 specimens, paratypes
- Farcimen (Farcimen) majusculum* ALCALDE, 1945  
1 specimen, cotype
- Farcimen (Farcimen) seminudum protractum* ALCALDE, 1945

- 1 specimen, cotype  
*Helix (Ampelita) sakalava* ANGAS, 1877  
 2 specimens, paratypes  
*Helminthoglypta crotalina* BERRY, 1928  
 6 specimens, paratypes  
*Helminthoglypta fontiphila* GREGG, 1931  
 18 specimens, paratypes  
*Lamellaria sharoni* WILLETT, 1939  
 1 specimen, paratype  
*Lithophaga attenuata rogersi* BERRY, 1957  
 2 specimens, paratypes  
*Littorina caliginosa* GOULD, 1849  
 5 specimens, paratypes  
*Macrarenne diegensis* McLEAN, 1964  
 6 specimens, paratypes  
*Micrarionta melanophylon* BERRY, 1930  
 3 specimens, paratypes  
*Mitra (Atrimitra) semiusta* BERRY, 1957  
 1 specimen, paratype  
*Mitrella lalage* PILSBRY & LOWE, 1932  
 2 specimens, paratypes  
*Nassarius howardae* CHACE, 1958  
 25 specimens, paratypes  
*Ocenebra keenae* BORMANN, 1946  
 3 specimens, paratypes  
*Oliva rejecta* BURCH & BURCH, 1962  
 1 specimen, paratype no. 19  
*Olivella (Olivella) sphoni* BURCH & CAMPBELL, 1963  
 1 specimen, paratype no. 4  
*Opisthosiphon (Bermudezsiphona) cucullatum* TORRE & BARTSCH, 1941  
 1 specimen, paratype  
*Opisthosiphon judasense* TORRE & HENDERSON, 1921  
 1 specimen, paratype  
*Opisthosiphon (Bermudezsiphona) obturatum sulcosum* TORRE & BARTSCH, 1941  
 1 specimen, paratype  
*Partula crassilabris* PEASE, 1866  
 1 specimen, paratype  
*Partula imperforata* "PEASE" GARRETT, 1884  
 1 specimen, paratype  
*Patella sagittata* GOULD, 1846  
 4 specimens, paratypes  
*Pedicularia ovuliformis* BERRY, 1946  
 1 specimen, paratype  
*Persicula bandera* COAN & ROTH, 1965  
 2 specimens, paratypes  
*Phidiana pugnax* LANCE, 1962  
 1 specimen, paratype  
*Pomatiopsis chacei* PILSBRY, 1937  
 169 specimens, paratypes  
*Pterotyphis (Tripterotyphis) fayae* KEEN & CAMPBELL, 1964  
 58 specimens, paratypes  
*Pyrene aureomexicana* HOWARD, 1963  
 155 specimens, paratypes  
*Scalina (Ferminoscala) billeeana* DUSHANE & BRATCHER, 1965  
 1 specimen, paratype  
*Siciliaria (Siciliaria) ferrox* BRANDT, 1961  
 1 specimen, cotype  
*Siciliaria (Siciliaria) nobilis episoma* BRANDT, 1961  
 1 specimen, cotype  
*Sinum cortezi* BURCH & BURCH, 1964  
 2 specimens, paratypes nos. 5 and 7  
*Stenacme floridana* PILSBRY, 1945  
 1 specimen, paratype  
*Terebra churea* CAMPBELL, 1964  
 1 specimen, figured paratype no. 1  
*Trochoidea (Xerocrassa) cretica beyedi* BRANDT, 1959  
 1 specimen, paratype  
*Trochoidea (Xerocrassa) forcarti* BRANDT, 1959  
 1 specimen, paratype  
*Trochoidea (Xeroptyca) serrulata jahamaensis* BRANDT, 1959  
 1 specimen, paratype  
*Trochomorpha contigua* PEASE, 1871  
 2 specimens, paratypes  
*Truncatella aurantia* GOULD, 1847  
 3 specimens, paratypes  
*Turritella anactor* BERRY, 1957  
 29 specimens, paratypes  
*Urocoptis livida barbouri* TORRE & CLENCH, 1930  
 1 specimen, paratype  
*Urocoptis heterosculpta* TORRE, 1932  
 1 specimen, paratype  
*Urocoptis lowei* "TORRE" PILSBRY, 1927  
 1 specimen, paratype  
*Vespericola karokorum* TALMADGE, 1962  
 4 specimens, paratypes  
*Volutocorbis lutosus* KOCH, 1948  
 1 specimen, paratype

In addition to the species listed above the Museum has some thirty additional specimens of *Urocoptis*. To the best of my knowledge, however, these have manuscript names only by TORRE & BARTSCH and are not listed here. The same applies to three *Partula* names of PEASE.

## HYPOTYPES

The Santa Barbara Museum of Natural History has most of the specimens cited by James McLean (1961) in his check list of Los Angeles Bay that were in the collection of Faye B. Howard. We also have most of the material cited by Helen DuShane (1962) in her checklist of Puertecitos that was in the collections of Faye B. Howard, Gale Sphon, and Homer P. King. These are not segregated, but are kept with the general systematic collection.

*Oliva venulata* LAMARCK, 1811

Nautilus, vol. 75, no. 4, plt. 17, upper and lower right figures. Figured hypotype.

*Pyrene fuscata* (SOWERBY, 1832)

Santa Barbara Mus. Nat. Hist. Occ. Pap. no. 7, plt. 1, figs. 4 and 5. Figured hypotype.

*Pterotyphis (Tripterotyphis) fayae* KEEN & CAMPBELL, 1964

63 specimens. Part of the authors' original material.  
*Terebra dushanae* CAMPBELL, 1964

5 specimens. Part of the author's original material.  
*Vexillum moanae* J. CATE, 1963

1 specimen. Part of the author's original material.

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DUSHANE, HELEN

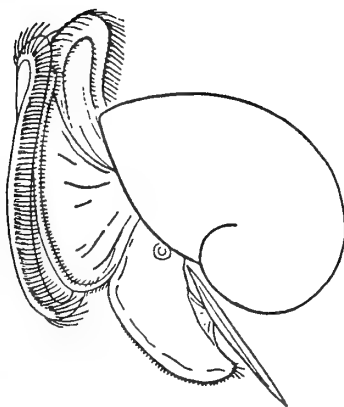
1962. A checklist of mollusks for Puertecitos, Baja California, Mexico. *The Veliger* 5 (1): 39-50; 1 map (1 July 1962)

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SPHON, GALE

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# The Use of Radiography for the Study and Identification of Spiral Marine Shells

BY

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(Plates 24 and 25)

## INTRODUCTION

RADIOGRAPHY is a particularly valuable tool for the study of hard tissues, and is capable of revealing internal structures which ordinarily are hidden by overlying calcifications, or which may be covered by soft tissues in the living animal. The use of radiographs for the study of various shells is an old one, and a number of authors have published photographs of radiographs as well as skiagrams of various shell specimens, e. g. MOORE (1955), ABBOTT (1954), VAN BENTHEM JUTTING (1952). THOMPSON (1942) reproduced the radiograph of a shell taken in 1897. Considering the value of the method and its long-time utilization, it is surprising that so little has been done with it in studying the various organisms with either internal or external shells.

The radiograph may be used to show degrees of calcification of various structures, the presence of incremental lines, the spiral forms of growth, major axes in growth, and other features. Excellent radiographs showing these features have been illustrated by CORNWALL (1959). Several techniques useful in studying shells radiographically and by other methods, including tracings of radiographic outlines and methods of orienting shells of the same species so that comparable radiographs may be taken, have been described by SPEER & HERZBERG (1961).

In addition to confirming the above uses of radiography, it is the aim of the present study to indicate its value as an additional means of identification for detecting various taxonomic levels, notably the family, in certain molluscan forms.

## ACKNOWLEDGMENTS

I gratefully acknowledge the most helpful suggestions made by Dr. Edwin L. Cooper, and the assistance of Miss

Katherine Hand and Miss Florence Davis who photographed the radiographs shown in this report.

## MATERIAL AND METHODS

Spiral shells of 12 families of marine gastropods identified at the generic and species level served as basis for this study.

All shells were radiographed with a standard dental roentgen-ray machine using the long cone technique at 67 kilovolts and 10 milliamperes, with a focal distance of 25 cm. The radiographs were photographed so that positive prints could be made, and these are presented for each specimen in this report.

## RESULTS

The family Muricidae in Plate 24, Figures 1 to 7 is represented by 7 species in 6 genera. While each species shows distinguishing features, including differences in ornamentation and in serrations of the shell lip, the family resemblance in columellar structure and general form of the shell is evident. It seems likely that the differences in apical angles may be characteristic of a genus, but the number of specimens available is insufficient to support this contention.

The family Trochidae, with 2 genera, each with 4 species, is illustrated in Plate 24, Figures 8 to 15. The genus *Tegula* shows a blunted and obtuse apical angle in each of the 4 species, while the genus *Calliostoma* shows a sharply pointed acute apical angle in its 4 species. In the case of the family Trochidae the 2 genera shown are clearly distinguishable from each other not only by differences in apex, but also by distinctly different columellar form and varying nature of their respective whorls. The sharp-

ness of the radiographic features of *Calliostoma* as compared to *Tegula* also are obvious. The species *C. tricolor*, while placed in the genus *Calliostoma*, appears to be almost intermediate in form between *Calliostoma* and *Tegula*. The radiographs of the genus *Tegula*, taken from above, clearly show the logarithmic spiral form of the shell.

Plate 25, Figures 16 and 17 show 2 genera, one species each, of the family Turridae. The 2 genera appear radiographically to be identical and could not be separated from each other on the basis of these photographs. Only family identification is feasible in this instance.

One species of the genus *Littorina*, family Littorinidae, is shown in Figure 18 of Plate 25.

The family Nassariidae is represented by 2 species of the genus *Nassarius*, in Figures 19 and 20. The acute apical angle appears to be characteristic of the genus, while the speckled form of shell calcification might well distinguish the species *N. perpinguis* from *N. fossatus*.

In Figures 21 and 22 are illustrated 2 species of the genus *Olivella*, of the family Olividae. These specimens resemble each other at the generic level.

Figures 23 to 28 show species from several families of spiral marine shells, and illustrate some of the variations mentioned between the several families, genera and species.

Figure 23: *Mitra idae*, Mitridae showing an unusual internal spiral centered around the columella.

Figure 24: *Norrisia norrisii*, Turbinidae.

Figure 25: *Zonaria spadicea*, Cypraeidae.

Figure 26: *Polinices reclusiana*, Naticidae.

Figure 27: *Cerithidea californica*, Cerithiidae.

Figure 28: *Conus californicus*, Conidae.

## DISCUSSION

From the evidence presented it appears logical to assume that the radiographic method could be used to assist in the identification of the spiral forms of shells at the level of the family, sometimes at the level of the genus, and some specimens probably could be identified as to species (Figures 19 and 20). Since the internal and external hard tissues of the shell vary little, if at all, from specimen to specimen of the same species, this tissue, because of its durability, could be used for making more positive identifications. Standards could be established for such identification if the various species were radiographed and a permanent record of their characteristics made. The simplicity of the radiographic technique would make such a project feasible for any investigator having the appropriate specimens available. This method could also be usefully applied to freshwater and land forms.

## Explanation of Plate 24

### Radiographs of shells of the family Muricidae

- Figure 1: Two specimens of *Maxwellia gemma* (SOWERBY, 1879)
- Figure 2: Two specimens of *Ceratostoma nuttallii* (CONRAD, 1837)
- Figure 3: Two specimens of *Shaskyus festivus* (HINDS, 1844)
- Figure 4: *Thais emarginata* (DESHAYES, 1829)
- Figure 5: *Thais* spec.
- Figure 6: *Ocenebra circumtexta* STEARNS, 1871
- Figure 7: *Acanthina spirata* (BLAINVILLE, 1832)

### Radiographs of shells of the family Trochidae

- Figure 8: *Tegula eiseni* JORDAN, 1936. The lower photograph is a view of the shell taken from the apex to show its logarithmic spiral form.

- Figure 9: *Tegula funebris* (A. ADAMS, 1854). Longitudinal and cross sectional views of two different specimens.
- Figure 10: *Tegula brunnea* (PHILIPPI, 1848). Longitudinal and cross sectional views of the same specimen.
- Figure 11: *Tegula aureotincta* (FORBES, 1850). Longitudinal and cross sectional views of the same specimen.
- Figure 12: *Calliostoma canaliculatum* (HUMPHREY, 1786)
- Figure 13: *Calliostoma gemmulatum* CARPENTER, 1864
- Figure 14: *Calliostoma annulatum* (HUMPHREY, 1786)
- Figure 15: *Calliostoma tricolor* GABB, 1865

## Explanation of Plate 25

### Radiographs of shells of the family Turridae

- Figure 16: *Burchia redondoensis* (BURCH, 1938)
- Figure 17: Two specimens of *Pseudomelatomia torosa* CARPENTER, 1865

### Radiograph of a shell of the family Littorinidae

- Figure 18: *Littorina planaxis* PHILIPPI, 1847

### Radiographs of shells of the family Nassariidae

- Figure 19: Three specimens of *Nassarius fossatus* (GOULD, 1862)
- Figure 20: Two specimens of *Nassarius perpinguis* (HINDS, 1844)

### Radiographs of shells of the family Olividae

- Figure 21: Two specimens of *Olivella biplicata* (SOWERBY, 1825)

- Figure 22: *Olivella baetica* MARRAT in SOWERBY, 1871

### Radiographs of shells of several marine gastropod families

- Figure 23: Two specimens of *Mitra idae* MELVILL, 1893 Mitridae.
- Figure 24: Two specimens of *Norrisia norrisii* SOWERBY, 1838 Turbinidae.
- Figure 25: *Zonaria spadicea* (SWAINSON, 1823) Cypraeidae.
- Figure 26: Two specimens of *Polinices reclusiana* (DESHAYES, 1839) Naticidae.
- Figure 27: *Cerithidea californica* (HALDEMAN, 1840) Cerithiidae.
- Figure 28: *Conus californicus* HINDS, 1844 Conidae.

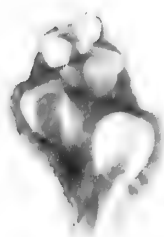


Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6



Figure 7



Figure 8

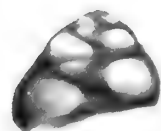


Figure 9



Figure 10



Figure 11



Figure 12



Figure 13



Figure 14

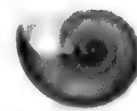


Figure 15







Figure 16



Figure 17



Figure 18

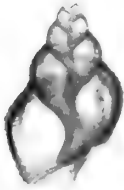


Figure 19

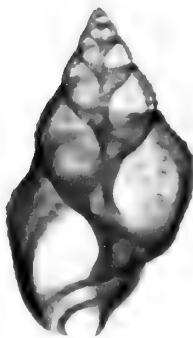


Figure 20



Figure 21



Figure 22



Figure 23

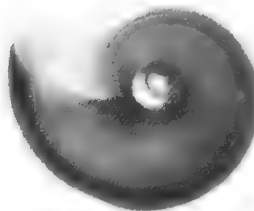


Figure 24

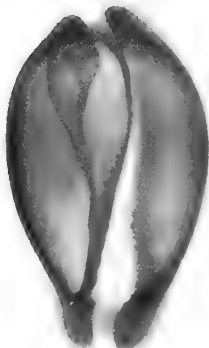


Figure 25

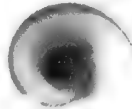
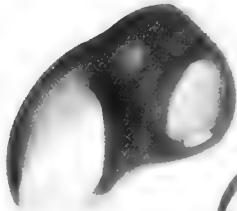


Figure 26



Figure 27

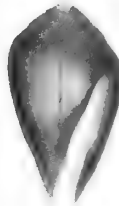


Figure 28



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## NOTES &amp; NEWS

Some Abnormal Chitons  
from Washington State

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544 A Union Street, Monterey, California 93940

THE OCCURRENCE OF ABNORMAL specimens of chitons, having more or fewer than the usual eight valves, has been noted in the literature (CHACE & CHACE, 1930; BERRY, 1935) for individuals of *Ischnochiton regularis* (CARPENTER, 1855), *Lepidozona mertensi* (MIDDENDORFF, 1846), and *Nuttallina fluxa* (CARPENTER, 1864), among West Coast species.

In recent months, the assiduous collecting of Emmeline (Mrs. A. R.) Wingard of Gig Harbor, Washington, has brought to light the following specimens, mostly from the Puget Sound area. Most show clearly the places where injuries have caused valves to grow together.

*Tonicella lineata* (WOOD, 1815). Port Orchard, (Kitsap County), Washington; 38.5 mm long, 19.7 mm wide, in dry state. Valves 7 and 8 fused completely into an abnormally large tail valve.

*Mopalia ciliata* (SOWERBY, 1840). Port Gamble (Kitsap County); 57 mm long, 24 mm wide. Seven-valved. Sixth-from-anterior valve with double slitting.

*Mopalia hindsii* (REEVE, 1847). Hadlock (Jefferson County); 66 mm long, 32 mm wide. Valves 7 and 8 fused,

incompletely on the left side, where a deep scar runs to the mucro and an extra insertion-plate is visible.

*Mopalia laevior* PILSBRY, 1918. Tacoma Narrows; 56 mm long, 29.5 mm wide. Apparently valves 5 and 6 have fused, the only evidence being the greater length of the valve and doubling of the slits in the right side insertion-plate.

*Mopalia laevior*. Indian Island (Jefferson County); 35 mm long, 24 mm wide. Six-valved, all valves appearing normal.

*Mopalia lignosa* (GOULD, 1846). Hadlock; 37 mm long, 20 mm wide. Seven-valved. It is not possible to tell which valves may have grown together.

*Mopalia lignosa*. Tacoma Narrows; 57 mm long, 31.2 mm wide. A very slight thickening shows that valves 6 and 7 have fused.

*Mopalia muscosa* (GOULD, 1846). Hale Pass; 74 mm long, 37.5 mm wide. Valves 4 and 5 fused, incompletely, so that insertion-plates of both valves are present on the left side.

*Mopalia muscosa*. Fort Ward, Bainbridge Island (Kitsap County); 56 mm long, 29.7 mm wide. Six-valved. Valves 4 and 5 have fused, and valves 6 and 7. The first abnormal valve has paired insertion-plates; the second, doubled lateral slits. Both valves show doubling on one side of the row of tubercles defining the lateral area.

*Mopalia swanii* CARPENTER, 1864. Tacoma Narrows; 42 mm long, 17.5 mm wide. Valves 7 and 8 incompletely fused.

*Katharina tunicata* (WOOD, 1815). Neah Bay (Clallam County); 73.5 mm long (valves only). Valves 6 and 7 fused, the insertion-plates for both traceable on the right side.

*Cryptochiton stelleri* (MIDDENDORFF, 1846). Fort Ward; valves 5 and 6 almost completely coalesced (see Figure 1).

These chitons are in the private collection of Mrs. Wingard, who displayed them at the 1966 meeting of the

American Malacological Union, Pacific Division. All are in a state of dry preservation. Some have had the girdle

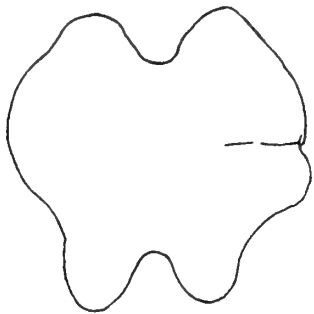


Figure 1

Abnormal Valve of *Cryptochiton stelleri* (MIDDENDORFF)  
Dorsal View x 0.8

removed so that the effect of the abnormality on the articulamentum may be seen.

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## A New Name for *Acmaea mitchelli* Lipps

JERE H. LIPPS

Department of Geology, University of California  
Los Angeles, California 90024

A. MYRA KEEN AND JAMES H. McLEAN have kindly informed me that *Acmaea mitchelli* LIPPS, 1963, described from the Pleistocene of San Nicolas Island, California, is preoccupied by *Acmaea striata mitchelli* OLDROYD, 1933. A new name, *Acmaea edmitchelli*, is here proposed. The new name preserves the original intent of recognizing Ed Mitchell's contributions to the paleontology of the California Channel Islands.

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1963. A new species of *Acmaea* (Archaeogastropoda) from the Pleistocene of San Nicolas Island, California. *Contrib. Sci., Los Angeles County Mus.*, no. 75, 15 pp.
- OLDROYD, IDA SHEPARD  
1933. Two interesting shells from the Philippine Islands. *Philipp. Journ. Sci.* 52 (2): 205-207; 1 plt.

## Confirmation of *Haliotis sorenseni* Bartsch at Isla Guadalupe, Mexico

EMERY P. CHACE

Natural History Museum of San Diego  
San Diego, California 92112

BARTSCH (1940, p. 50) described *Haliotis sorenseni* and reported it from "slightly south of Point Conception, California" and "some islands off shore probably Guadalupe." It seems not to have been cited since from Isla Guadalupe. A single adult specimen referable to this species recently presented to the Natural History Museum of San Diego by Dr. Carl L. Hubbs of Scripps Institution of Oceanography confirms BARTSCH's record.

Dr. Hubbs reports that this specimen was recognized and picked up on "Barracks Beach" at Northeast Anchorage of Isla Guadalupe by David L. Leighton on February 28, 1965, while on a trip there supported by National Science Foundation Grant G.B.-508 to C. L. Hubbs. The soft parts of the animal were intact although a small fragment was newly broken from the anterior lip of the shell. Several specimens of *Balanus trigonis* DARWIN, 1854 on the shell were identified by Dr. William A. Newman of Scripps Institution of Oceanography.

The bathymetric range of *Haliotis sorenseni* elsewhere is 15 to 150 feet or more, but mainly below 80 feet (BARTSCH, 1940, p. 50; COX, 1960, p. 398; 1962, p. 40). Dr. Hubbs speculates that the unusual presence on an uninhabited beach of a newly dead and broken abalone of probably deeper water origin than that in which divers commonly operate might be attributed to "collection by the northern elephant seal *Mirounga angustirostris* (GILL, 1866) which is abundant at this beach."



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1962. California abalones, family Haliotidae. Fish Bull. 118, Calif. Dept. Fish and Game, Sacramento, Calif.

in your animal are just like those observable on our specimens -- no local differentiation of colours could be recognized." This species has been recorded from Sagami Bay and Amakusa, Japan. This report is the first record of the genus *Berghia* from the East Pacific. The figure (Figure 1) was drawn from a color transparency of the animal from Puertecitos.

MARCUS (1958, pp. 68-69) suggests that the part of the genus *Baeolidia* including the three forms of BABA should be transferred to *Berghia*, based on anatomical characteristics.

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MARCUS, ERNST

1958. On western Atlantic opisthobranch gastropods. Am. Mus. Novitates no. 1906; pp. 1-82; figs. 1-111

## Range Extension of *Berghia amakusana* (Baba) to the East Pacific

WESLEY FARMER

ON 1 DECEMBER 1963 I collected a nudibranch of the genus *Berghia* in a tidepool one mile north of Puertecitos in the Gulf of California, Baja California, Mexico. It measured 20 mm in length and was colored as follows: body was yellowish brown; the cerata were yellowish brown with yellowish blotches; near the tips of the cerata there was a light bluish ring and distally a ring of yellowish color; the tips of the cerata were whitish. In the center of the head, between the oral tentacles and rhinophores there was a dark spot surrounded by a ring of yellowish color. The oral tentacles were yellowish brown covered with yellowish blotches. The radula formula was  $22 \times 0 \cdot 1 \cdot 0$ .

A color slide of this animal was submitted to Doctor Kikutarô Baba who identified it as *Berghia amakusana* BABA, 1937). He wrote "The various colours displayed

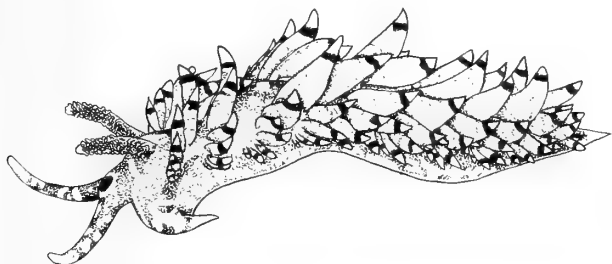


Figure 1

*Berghia amakusana* (BABA, 1937)

## METHODS &amp; TECHNIQUES

## A Technique for Observing Ctenidial and Mantle Currents in Limpets

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Dillon Beach, California 94929

IN THE STUDY of the functional morphology of limpets, the water movements within their mantle cavities are often of significance. The following is a method by which the ctenidial and mantle currents can be observed.

Ctenidial currents can best be studied while the limpet is in an inverted position. The shell apex should be lodged against a small piece of clay and pressed to the bottom of a glass dish filled with sea water. When the limpet tries to right itself (Figure 1), it usually exposes its ctenidia. The ctenidial currents can be easily determined by pipetting a suspension of carmine in sea water into its mantle cavity and tracing the particles of carmine using a dissecting microscope. Some workers prefer to place a glass microscope slide against the limpet's foot and permit the gastropod to hang inverted, using the slide as support. It has been my experience that in using the latter method the limpet's foot generally obscures the view of the ctenidia.

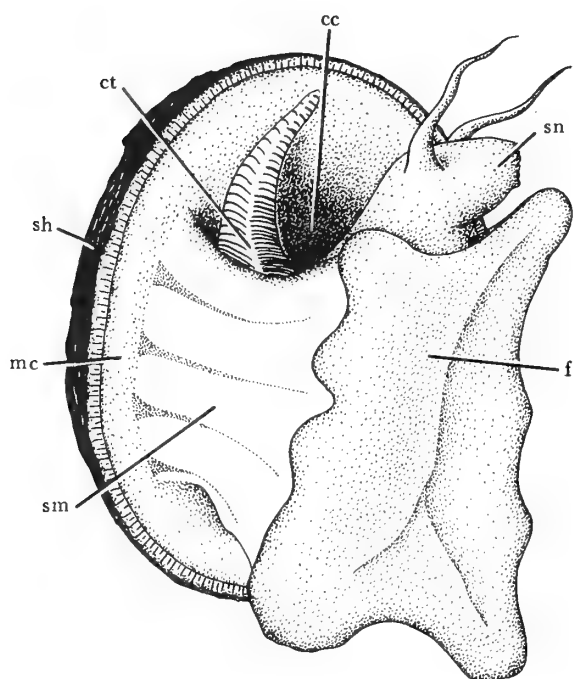


Figure 1

Ventral Aspect of the Marine Limpet *Acmaea* in the Inverted Position.

cc - central compartment of mantle cavity  
 ct - ctenidia      f - foot      mc - mantle cavity      sh - shell  
 sm - shell muscle      sn - snout

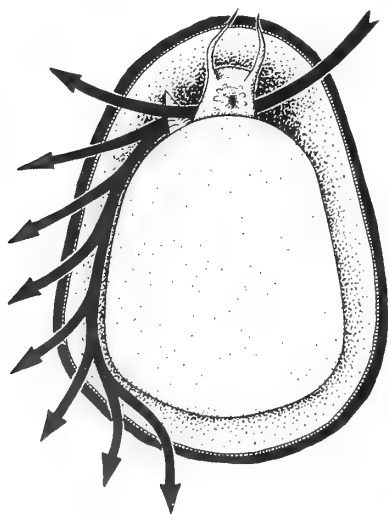


Figure 2

The Set-Up of Apparatus for Observing the Ventral Aspect of a Limpet Through the Bottom of a Glass Dish

The study of a limpet's mantle currents while the mollusk is attached to its normal substrate is impractical. It is feasible to replace the substrate with a flat-bottomed glass dish having minimal optical distortion, and mounting a dissecting microscope so that the worker is looking up through the bottom of the dish at the ventral aspect of the limpet (Figure 2). The advantages of observing the mantle currents while the limpet is upright are that in this realistic position the effects of the foot, shell, mantle cavity, ctenidia, and substrate on these currents are demonstrated (Figure 3). By injecting a carmine-sea water suspension into the mantle cavity and observing the direction of particle movement, the mantle currents can be determined.

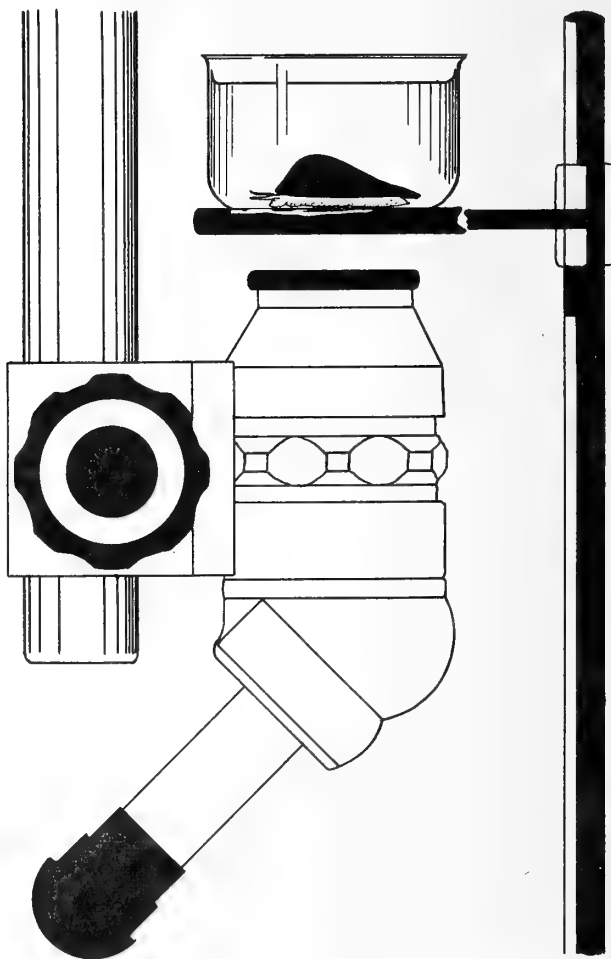


Figure 3

Ventral Aspect of the Limpet *Acmaea* as seen Through the Bottom of a Glass Dish. The Limpet is in an Upright Position. Arrows Indicate the Direction of Water Circulation

## BOOKS, PERIODICALS, PAMPHLETS

## British Bivalve Seashells.

By NORMAN TEBBLE. London: British Museum (Natural History). Pp. 1 - 212; 110 figs. in text, 12 pls. (8 in color). Paper-back, 14 shillings; bound, 20 shillings (\$2.00; \$3.00 respectively; postage 15 cents extra).

Although the subtitle describes this as a handbook for identification, it will have a wider use than as an introductory guide for the amateur collector. There is much useful information on distribution, variation, and ecology. Not only are the genera and species distinguished by well-considered keys, but there are excellent line drawings of the interiors for all species. Photographic plates in both black-and-white and in color add a final touch of elegance to the book. Taxonomic problems have, understandably, been given minimal emphasis, but the nomenclature is as up-to-date as one could ask, and under the caption "Special References" at appropriate places in the text, papers dealing with individual species are cited. The text has been carefully prepared and proof-read, and the book is one that can be recommended to collectors everywhere.

MK

**Revision of the Pelecypods from the Michael Sars North Atlantic Deep-Sea Expedition 1910 with notes on the Verticordiidae and other interesting species.**

By T. SOOT-RYEN. Sarsia (Univ. Bergen), No. 24, pp. 1 to 31, pls. 1 to 3, figs. 1 to 15 in text. April 30, 1966.

This paper contains a revision of 36 species, distributed in 18 families, assembled during a cruise of the *Michael Sars* in the North Atlantic in 1910. They are from 10 stations at depths varying from 77 to 2865 m from off the coasts between northwest Africa to Scotland, and from south of the Azores and from off Nova Scotia.

The families Pholadomyidae (pp. 10-15) and Verticordiidae (pp. 15-27) are extensively discussed, the latter with a synoptic revision containing 18 supraspecific groups. Nine species and one subspecies originally described in the genus *Lyonsiella*, including the west American *L. alaskana* DALL, are assigned to the genus *Policordia* DALL, BARTSCH, & REHDER, 1938. Five species, including the west American *L. magnifica* DALL, are retained in *Lyonsiella*.

The discussions and illustrations of many rare and deep-sea species in this paper will greatly aid others who study benthic bivalve mollusks.

LGH

**A Preliminary Checklist of Invertebrates collected from Lake Tahoe, 1961 - 1964.**

By TED C. FRANTZ and ALMO J. CARDONE. Biological Society of Nevada Occ. Pap. 8: 1 - 12 (15 January, 1966).

Seven species of mollusks are recorded (with depth ranges) from localities in Lake Tahoe, in both Nevada and California. All were identified by W. J. Clench, who "... stated that one badly corroded snail may be in the genus *Littoridina*." This genus of Hydrobiidae has not been previously found north of the American tropics, so attempts to collect additional material would be especially worthwhile.

Thanks are due Mr. Gary Pace, University of Michigan Museum of Zoology, for drawing my attention to this paper.

D. W. Taylor.

**Mattheva, a proposed New Class of Mollusks.**

By ELLIS L. YOCHELSON. U. S. Geol. Survey, Prof. Paper 523-B, 11 pp., 3 figs. 1966.

The conventional five classes of mollusks have been increased in recent years by the recognition of some extinct groups - one of which, the Monoplacophora, later was discovered living. The new Class *Mattheva* is based upon a single genus, *Matthevia*, that occurs at a number of localities in the late Cambrian of North America. The shell apparently consists of two slipper-shaped valves that were oriented anteriorly and posteriorly over the body of a gastropod-like mollusk.

MK

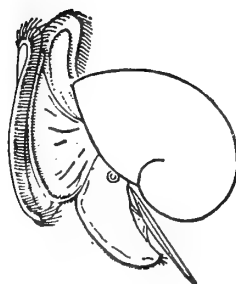
**A new *Rosalina* (Foraminifera) Parasitic on a Bivalve.**

By RUTH TODD. Deep-Sea Research, 1965, vol. 12, pp. 831 - 837, pls. 1 - 3.

This paper describes and well illustrates an unusual association of a mollusk and a foraminiferan. The new species of foraminifera, *Rosalina carnivora*, was found attached to the exterior of a *Lima (Acesta) angolensis* ADAM & KNUDSON dredged from the Gulf of Guinea. The foraminifera caused pits in the areas of their attachment, and some of these actually penetrated the *Lima* shell. Penetration of the shell caused the secretion of additional shell material on the interior of the valve, indicating that the clam was alive during the pitting by the foraminifera. The author believes that the pitting of the *Lima* shell by the foraminifera occurred for one of two possible reasons: 1) to obtain nourishment from the mantle of the clam, a speculation later dismissed; or

2) to obtain calcium carbonate for the construction of its own test. It is also possible that the foraminifera merely sought secure attachment and protection, and that

the pitting of the clam shell resulted from this cause, rather than a need for calcium carbonate, which is normally saturated in sea water. Jere H. Lipps.



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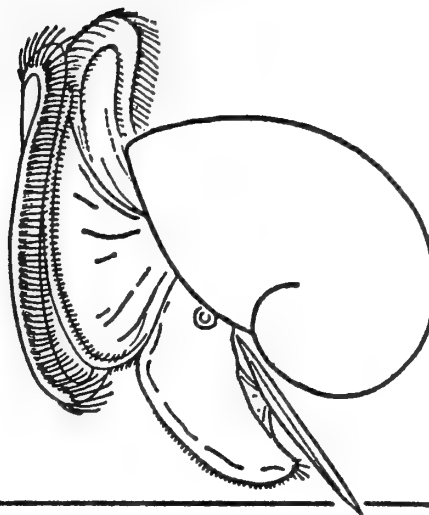
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, Subdivision, SECTION,  
 SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).  
***New Taxa***



# The Egg Masses and Veligers of Thirty Northeast Pacific Opisthobranchs

BY

ANNE HURST

University of Washington

Friday Harbor Laboratories, Friday Harbor, Washington 98250<sup>1</sup>

(Plates 26 to 38; 31 Text figures)

## INTRODUCTION

SINCE THE VELIGERS of opisthobranchs are released in huge numbers from rather conspicuous egg masses, it is somewhat surprising that little has been systematically recorded concerning these or other young stages. Identification is thus a formidable task. While an exhaustive survey is required to cover the problem, the present work provides new information in a format suitable for organized use of further comparative data. Amongst previous authors O'DONOGHUE & O'DONOGHUE (1922) working on Northeast Pacific forms, THORSON (1946), THOMPSON (1961) and HADFIELD (1963) have summarized much of the information available.

The animals included here were collected off the San Juan Islands, Washington, in the vicinity of the Friday Harbor Laboratories. Adults, egg masses and veligers were kept in running or frequently renewed sea water. Most species are common in the area but a few have not been recorded there previously: these are marked with an asterisk in the following list.

- Acanthodoris brunnea* MACFARLAND, 1905
- Acanthodoris hudsoni* MACFARLAND, 1905
- Acanthodoris nanaimoensis* O'DONOGHUE, 1921
- Aeolidia papillosa* (LINNAEUS, 1761)
- Aglaja diomedea* (BERGH, 1893)
- Archidoris montereyensis* (COOPER, 1862)
- Armina californica* (COOPER, 1862)
- \* *Austrodothis odhneri* MACFARLAND, 1966
- \* *Catrina aurantia* (ALDER & HANCOCK, 1842)
- \* *Chelidonura phocae* MARCUS, 1961

- Coryphella fusca* O'DONOGHUE, 1921
- ? *Coryphella rufibranchialis* (JOHNSTON, 1832)
- \* *Cratena albocrusta* MACFARLAND, 1966
- \* *Cumanotus beaumonti* (ELIOT, 1908)
- Dendronotus frondosus* (ASCANIUS, 1774)
- Dendronotus iris* COOPER, 1863
- Diaulula sandiegensis* (COOPER, 1862)
- Dirona albolineata* COCKERELL & ELIOT, 1905
- Dirona aurantia* HURST, 1966
- Eubranthus olivaceus* (O'DONOGHUE, 1922)
- Gastropteron pacificum* BERGH, 1894
- Haminoea virescens* (SOWERBY, 1833)
- Hermisenda crassicornis* (ESCHSCHOLTZ, 1831)
- Melibe leonina* (GOULD, 1853)
- Olea hansineensis* AGERSBORG, 1923
- Onchidoris bilamellata* (LINNAEUS, 1767)
- \* *Onchidoris muricata* (MÜLLER, 1776)
- Rostanga pulchra* MACFARLAND, 1905
- Triopha carpenteri* (STEARNS, 1873)
- Tritonia exsulans* BERGH, 1894

## EGG MASSES

The eggs of opisthobranchs are enclosed in capsules which in turn are deposited within a jelly-like material which swells to a variable extent in contact with sea water, as described by PRUVOT-FOL (1954). A definite egg string containing the capsules is often visible within the jelly as described by O'DONOGHUE & O'DONOGHUE (1922) but it is not always readily apparent. The egg mass may take one of several forms, depending on the manner of laying and the anatomy of the reproductive tract. The most usual forms are as follows:

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**Type A:** The egg mass is in the form of a ribbon attached along the length of one edge, capsules occurring throughout most of it. This is common amongst dorids, which whilst laying may grip the mass between foot and mantle edge (Text figure 4b) tending to flatten it, as mentioned by FRETTER & GRAHAM (1964). This is probably not the sole cause of the flattened shape.

**Type B:** The egg mass is in the form of a cylindrical capsule-filled cord usually attached along one side by a thin jelly sheet (free of capsules) which may be wide or narrow. This is the usual form produced by aeolids and sacoglossans, the egg masses of the latter being particularly closely attached to the substratum (i. e. the jelly-free sheet is very narrow).

Types A and B are usually coiled since the parent crawls in a spiral whilst laying its eggs, as described by ALDER & HANCOCK (1845 - 1855). As these authors noted, however, the coiling may be more or less completely disguised when the mass is laid on other than a flat substratum.

**Type C:** The egg mass is in the form of an ovoid or globular jelly bag attached by a jelly string. This is common amongst cephalaspideans.

**Type D:** The egg mass is a small structure, often sac-like, and attached at one side. It may be similar to Type A or B but if coiled turns less than one complete circuit. It is typical of very small aeolids.

The egg masses of the species listed in the introduction will be considered in these four groups. The possession of a particular complex of characteristics distinguishes the egg mass of any species: the most useful diagnostic features of opisthobranch egg masses are tabulated for each type (Tables 1 - 8) and additional comparative notes and illustrations given below. The months in which egg masses were found (Tables 1, 3, 5, 7) represent, to some extent, times of observation and may not reflect seasonal laying except where stated. Seasonal laying in this area may be different from that of other regions with different seasonal or ecological conditions. The variety of months in which opisthobranchs lay their eggs is much wider than supposed by O'DONOGHUE & O'DONOGHUE (1922).

The number of egg masses examined for each species varied from 1 to 14 and averaged 6. Where great intra-specific variation occurred it has been noted. In cases where several egg masses were laid by the same animal wide variation occurred at times between the first and last egg mass observed - the last often contained many fewer eggs, but the dimensions of both eggs and capsules (Tables 2, 4, 6, 8) remained constant. The terminal part of the last egg mass very frequently had less eggs per capsule and sometimes empty capsules, presumably because no more eggs were available. The size of the mass laid (Tables 1, 3, 5, 7) also varied to some extent with

the size of the parent, as noted by O'DONOGHUE & O'DONOGHUE (1922). Thus the maximum, minimum and average measurements given do not represent absolutes, but do provide a reliable guide to sizes involved. The number of eggs per egg mass has not been included since it has not proved particularly constant or diagnostic.

The colour of the egg masses (Tables 1, 3, 5, 7) sometimes varies with age but not to any great extent in the species included here. Water temperature has not fluctuated widely (8° to 11° C) but hatching time (Tables 2, 3, 6, 8) has sometimes been variable. However, time taken to hatch has been similar to comparable times found by previous workers which have been summarized by HADFIELD (1963). Hatching time is influenced by other factors besides temperature: egg masses hatch earlier if placed in a strong water current and may be caused to hatch by addition of fresh sea water. This may be due to the effect of a good oxygen supply, change in osmotic conditions, or to a mechanical cause. Egg masses are less infested by such animals as copepods and protozoans when placed in a good water circulation and the contents of many become unhealthy where this is not available. The veliger type (using the terminology of THOMPSON, 1961) has been included in the egg mass tables (Tables 2, 3, 6, 8) and is further discussed below.

#### Egg Masses of Type A

In this type the appearance of the ribbon depends greatly on the relative lengths of the free and attached edges. Thus in the egg mass of *Acanthodoris hudsoni* (Text figure 2) the longer free edge is fluted resembling a rosette, whilst that of *Diaulula sandiegensis* (Text figure 4a) is only slightly wavy at intervals since there is little difference in length between the free and attached edges. Where the free edge is shorter than the attached one the ribbon slopes inwards to the centre of the coil as in *Onchidoris muricata* (Text figure 8). The degree of stiffness of the ribbon (largely depending on its thickness) also affects the general appearance of the egg mass - whether it flops in folds as in that of *Austrodoris odhneri* (Text figure 5) and *Melibe leonina* (Text figure 7a), or stands erect as does that of *Haminoea virescens* (Text figures 6a, b). The closeness and regularity of coiling is variable although some species habitually lay very neat coils e. g. *Acanthodoris hudsoni* (Text figure 2), *A. nana-imoensis* (Text figure 3), *Onchidoris muricata* (Text figure 8); others rarely lay in a spiral e. g. *Onchidoris bilamellata*; others as commonly lay in a random direction as in a regular coil e. g. *Haminoea virescens* (Text figure 6a), *Melibe leonina* (Text figure 7a). In some egg masses the egg string is so easily detected in the field that the ribbon appears to be striated as in those of *Triopha*

*carpenteri* and *Haminoea virescens* (Text figures 6a, b). In several cases the situation of the egg mass is helpful. Such gross observations are summarized in Table 1 and Text figures 1-9, whilst those based on more detailed study are included in Table 2 and Plates 26-28.

*Acanthodoris brunnea*, Text figure 1; Plate 26, Figure 1

The egg masses are found on intertidal rocks in great abundance in early summer. The ribbon is laid in an

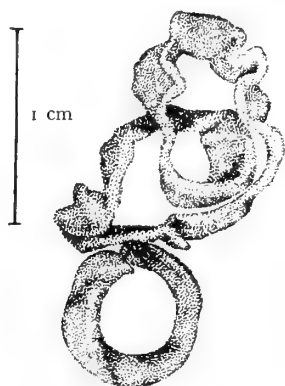


Figure 1

Egg Mass of *Acanthodoris brunnea*

untidy criss-crossing coil and is often almost as thick as it is wide. There is a narrow, clear area of jelly along both its edges. The capsules are well-spaced, frequently by almost their own width and their walls are thick and smooth.

*Acanthodoris hudsoni*, Text figure 2; Plate 26, Figure 2

The white ribbon forms a neat, closely coiled egg mass, usually with  $1\frac{1}{2}$  to 2 whorls. Its free edge is considerably longer than the attached one and since the ribbon is fairly

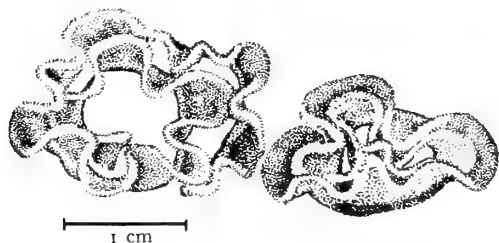


Figure 2

Two Egg Masses of *Acanthodoris hudsoni*

thick and stiff, the whole mass forms a fluted rosette. The capsules are spaced as in *Acanthodoris brunnea*, tending to be relatively thicker-walled and, in some specimens, more oval. The eggs are yellowish.

*Acanthodoris nanaimoensis*, Text figure 3; Plate 26, Fig. 3

Egg masses were laid on rocks and empty shells in the laboratory. The ribbon is very closely coiled, fairly thick and upright, taking a rounded course of 2 to 3 whorls, depending on the size of the parent. O'DONOGHUE & O'DONOGHUE (1922) reported the ribbon as yellow, with a wide, transparent margin, but in the present study all egg masses



Figure 3

Egg Mass of *Acanthodoris nanaimoensis*

were creamy-white with a narrow transparent margin at the free edge. Whereas the O'DONOGHUES' ribbons were 0.89 cm in width, the present ones were 0.45 to 0.50 cm. A ribbon of 9.20 cm length formed a spiral of about 1.50 cm diameter. The capsules are spaced out as in other acanthodorids. They are widely oval, with smooth, thick walls, and some are pointed at one end. Capsule dimensions (Table 2) were a little larger than those measured by O'DONOGHUE & O'DONOGHUE (the 1922 measurements were: 80 to 90  $\mu$  by 90 to 100  $\mu$ ).

*Archidoris montereyensis*, Text figs. 4a, b; Plate 27, Fig. 5

The egg mass of this species may be found at any time of year, usually on rocks where there is a strong current flow. Varying from bright yellow to very pale cream, the mass is laid in a fairly close coil occasionally trailing off to a straight terminal part. The ribbon is relatively thicker than that of *Austrodoris* and hence more erect (masses often consist of several more whorls than that in Text figure 4a). The free edge is a little longer than the attached one and splays out but is not usually fluted. It is also often the thicker edge and has a narrow, transparent margin. The usual ribbon width is 1.50 to 2.50 cm. As O'DONOGHUE & O'DONOGHUE (1922) mentioned, an egg string is present within the ribbon, but usually it is not at all obvious in the field. Each rounded capsule has a very thick, sculptured wall and contains 1 to 2 eggs, though in some masses capsules may contain 3 eggs. O'DONOGHUE

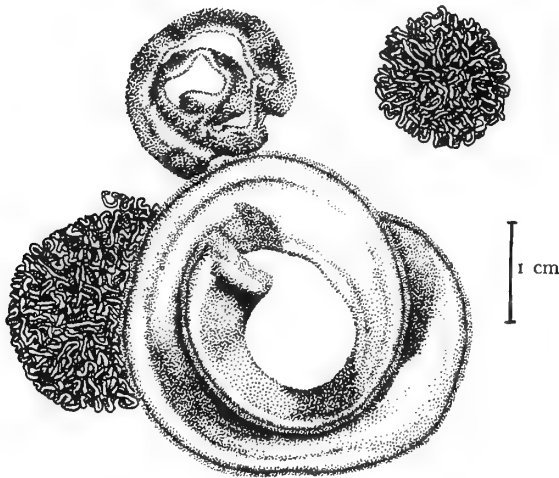


Figure 4 a

Egg Masses of *Archidoris montereyensis* (lower right), *Diaulula sandiegensis* (upper left), *Hermisenda crassicornis* (upper right and lower left)

& O'DONOGHUE found only 1 egg per capsule and the capsule size ( $120$  to  $160\mu$  by  $140$  to  $210\mu$ ) is at variance with present measurements (Table 2).

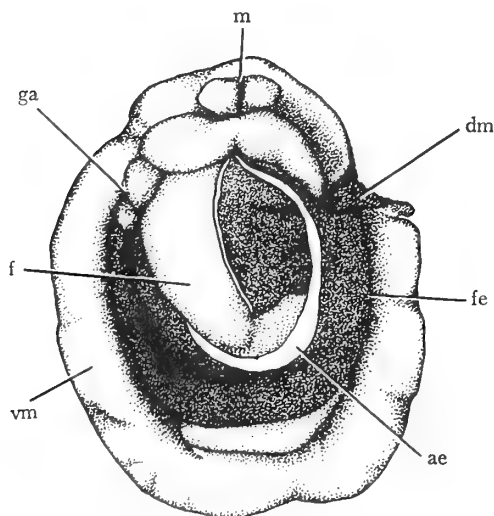


Figure 4 b

Ventral View of *Archidoris montereyensis* laying an Egg Mass  
 ae - attached edge of egg mass    fe - free edge of egg mass  
 dm - dorsal side of mantle        ga - genital aperture  
 f - foot                                m - mouth  
 vm - ventral side of mantle

*Austrodoris odhneri*, Text figure 5; Plate 26, Figure 4

In the aquarium, the egg masses were always deposited where there was a rather strong current flow. This is advantageous in keeping the ribbon clean of infesting animals, particularly useful in this case since the ribbon is relatively thin as well as wide and flops in folds which otherwise cling together closely, forming a sheltered hab-

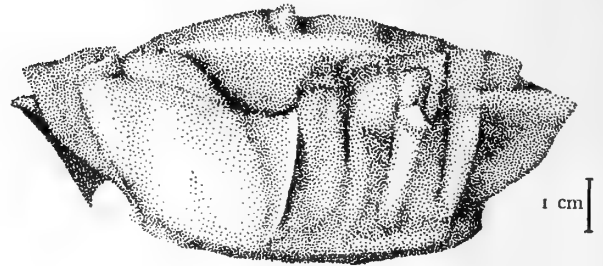


Figure 5

Egg Mass of *Austrodoris odhneri*

itat for protozoans and copepods. The very wide ribbon ( $3.30$  to  $4.70$  cm) is laid in an oval spiral, and its free edge is longer than the attached one. The capsules are closely packed, sometimes touching. They are rather rounded with smooth, thick walls and usually contain 8 to 12 eggs, but sometimes there are fewer, particularly at the outermost, ultimate part of the ribbon.

*Diaulula sandiegensis*, Text figure 4 a; Plate 27, Figure 6

The egg masses were found attached below overhanging edges of intertidal rocks. The white (much less commonly cream) ribbon is relatively narrow, (about  $0.40$  cm) and has 3 to 8 whorls, according to the size of the adult. (The egg mass in Text figure 4 a was the third laid by one animal and is thus unusually short.) A coil with diameters  $2.0$  and  $3.50$  cm took three hours to lay and was laid in a typically oval spiral. The turns of the coil are rather close and sometimes appear crowded due to waviness of the upper edge, which is not, however, much longer than the attached edge. The egg string is usually fairly obvious and may sometimes be detected in the field. The slightly oval capsules are arranged closely, overlapping but not joining. There are 1 to 2 eggs per capsule. Capsule dimensions overlapped with those measured by O'DONOGHUE & O'DONOGHUE (1922) whose capsules were a little smaller.

*Haminoea virescens*, Text figures 6 a, b, c

The untidy yellow egg masses were found on *Ulva*, *Vaucheria* and *Zostera* in sheltered bays and lagoons with

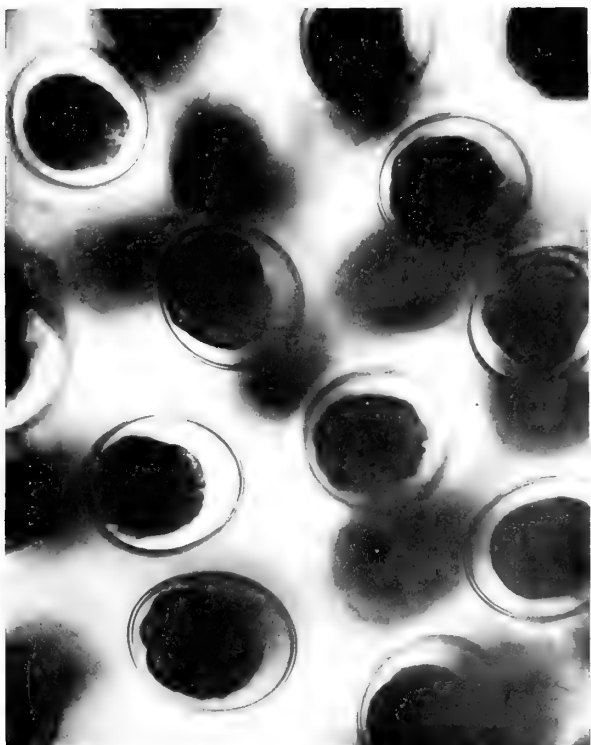


Figure 1: Egg Mass of *Acanthodoris brunnea*

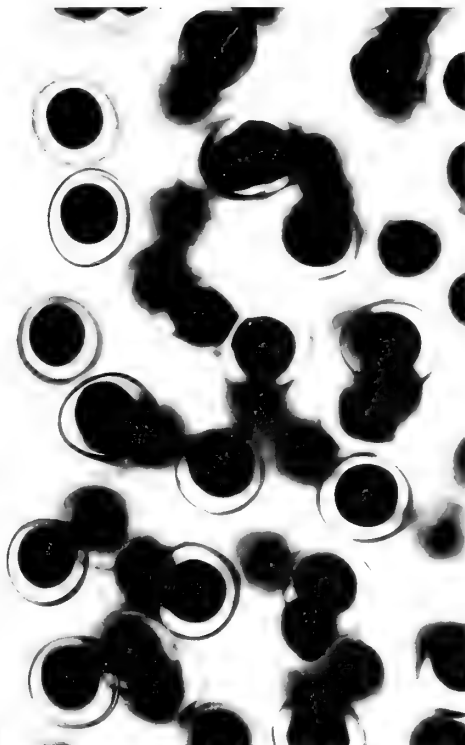


Figure 2: Egg Mass of *Acanthodoris hudsoni*



Figure 3: Egg Mass of *Acanthodoris nanaimoensis*

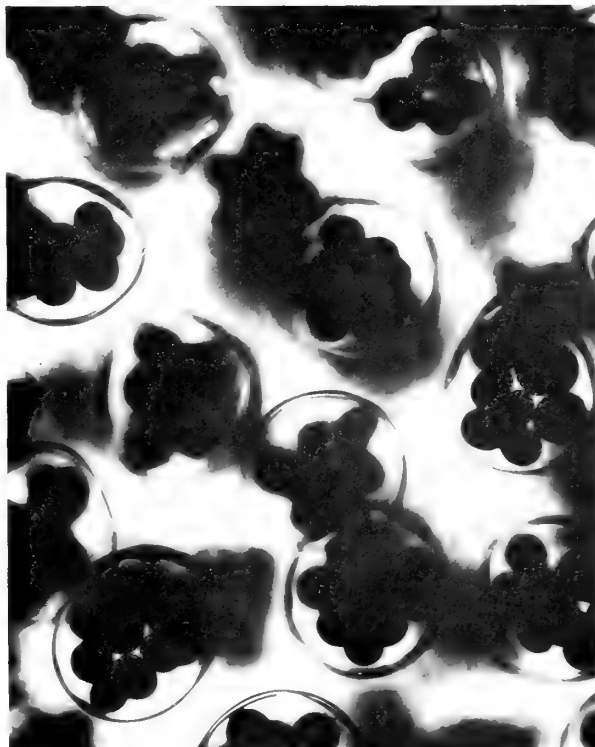


Figure 4: Egg Mass of *Austroderis odhneri*



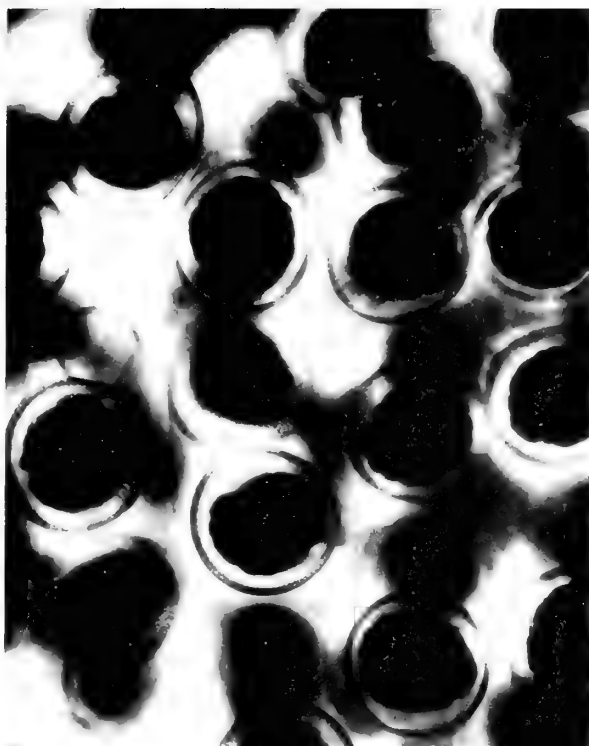


Figure 5: Egg Mass of *Archidoris montereyensis*



Figure 6: Egg Mass of *Diaulula sandiegensis*

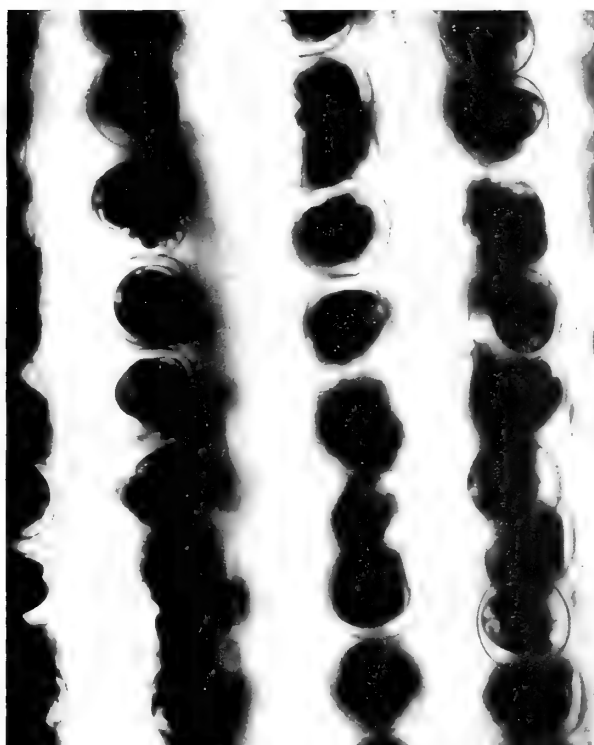


Figure 7: Egg Mass of *Haminoea virescens*



Figure 8: Egg Mass of *Melibe leonina*





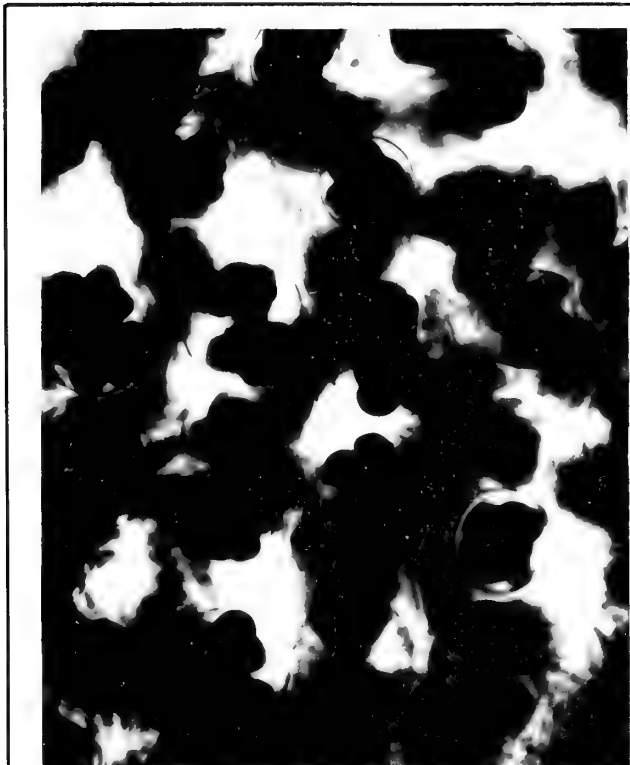


Figure 9: Egg Mass of *Onchidoris bilamellata*

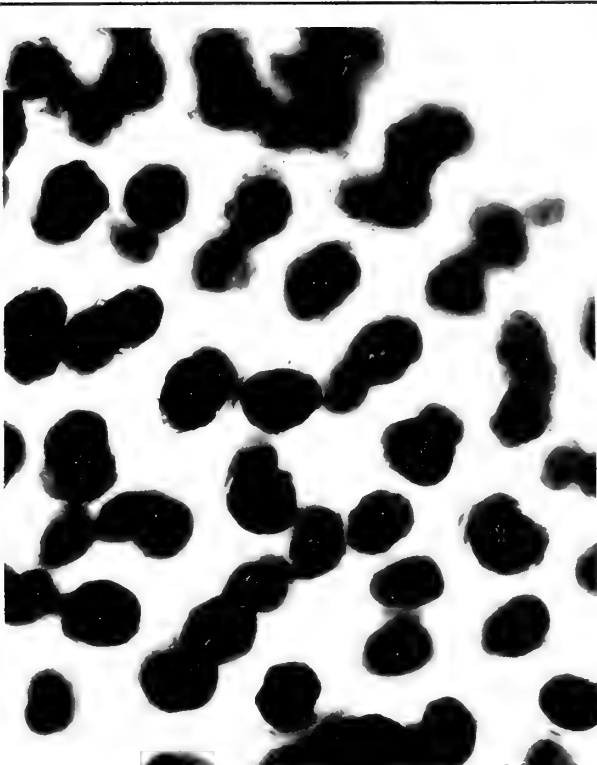


Figure 10: Egg Mass of *Onchidoris muricata*



Figure 11: Egg Mass of *Rostanga pulchra*

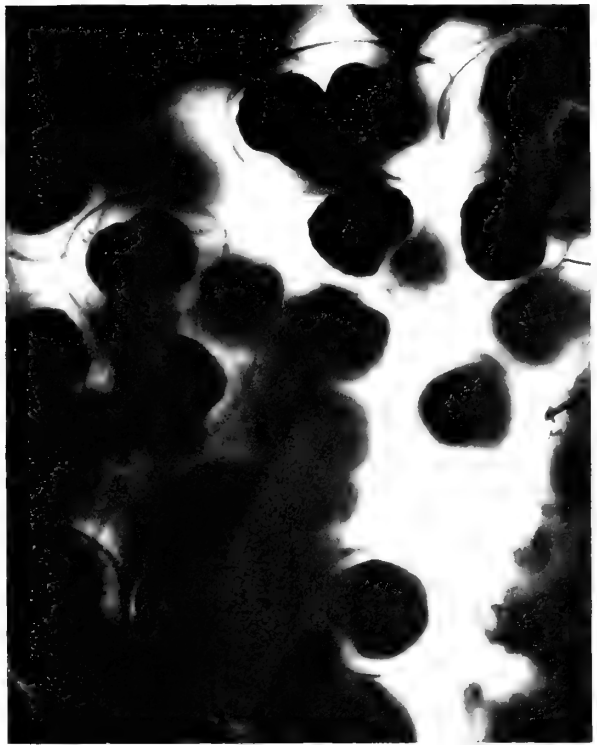


Figure 12: Egg Mass of *Triopha carpenteri*



a fine gravel or sandy substratum. They were attached in an unevenly coiled or meandering line and were striated in appearance due to the very obvious egg string. The free edge has a clear margin and is equal in length to the

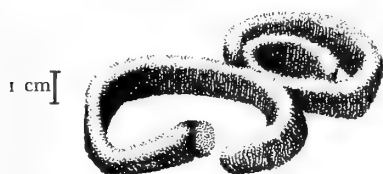


Figure 6a

Two Egg Masses of *Haminoea virescens*

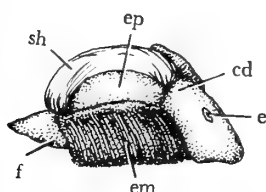


Figure 6b

Right Lateral View of *Haminoea virescens* laying an Egg Mass

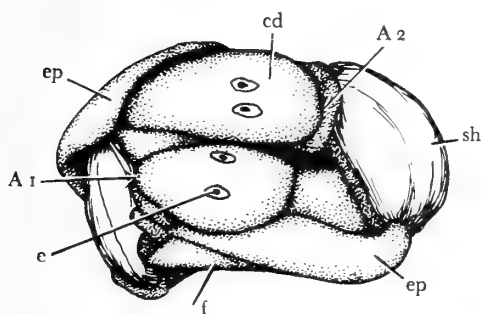


Figure 6c

Dorsal View of Two *Haminoea virescens* in coitus

A1 - anterior end of first animal      em - egg mass  
A2 - anterior end of second animal    ep - epipodium  
cd - cephalic disc                      f - foot  
e - eye                                      sh - shell

attached edge. The ribbon stands erect, being about 0.2 cm thick and 0.8 to 1.10 cm wide. The average length of an egg mass is 5 to 6 cm. The capsules touch each other along the egg string but not between adjacent coils of

this. Individual capsules may be attached to their neighbour by a fine connection as is frequent in cephalaspidean egg masses, and also in *Elysia* (REID, 1964). The capsule walls are smooth and either rounded or oval in outline. In most egg masses there was 1 egg per capsule but a few contained many capsules with 2 eggs. The characteristic yellow colour is due to the contents of the developing eggs and later to those of the the veliger digestive glands.

*Melibe leonina*, Text figures 7a, b; Plate 27, Figure 8

The egg masses are attached to kelp, or, more commonly, to *Zostera* well below the tidal region. They are very distinctive although width varies (less than 1.0 to 3.50 to 4.50 cm) and so does length (2.50 to 12.50 cm). The larger dimensions are more common and colour is

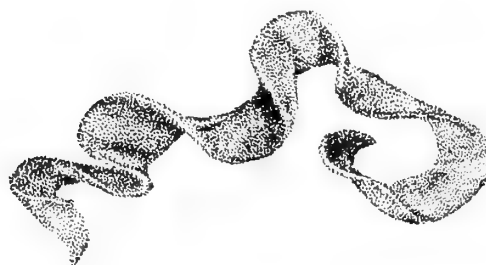


Figure 7a

Egg Mass of *Melibe leonina*

usually cream. The free edge of the egg mass is longer than the attached one, as AGERSBORG (1921) and O'DONOGHUE & O'DONOGHUE (1922) have reported. This often results in a funnel-shaped appearance (as in AGERSBORG's photograph), but the mass is not necessarily laid in a tight coil and may hang in wavy folds as in Text figure 7a and in the O'DONOGHUES' photograph. A wide basal area of the ribbon may be free of capsules, as may be its terminal end. The capsules may be close-packed or narrowly separated. They are large and oval, but frequently have flattened sides if much crowded. Most contain 15 to 25 eggs and only sometimes appear arranged in fairly regular lines as AGERSBORG described. Smaller egg masses may have fewer eggs per capsule, especially if the mass is the last laid over a short period of several layings by one adult. As few as 5 eggs per capsule may occur and frequently only 8 occur - less than has previously been described. However the general size range of egg masses, capsule size and number of eggs per capsule agree with earlier observations.

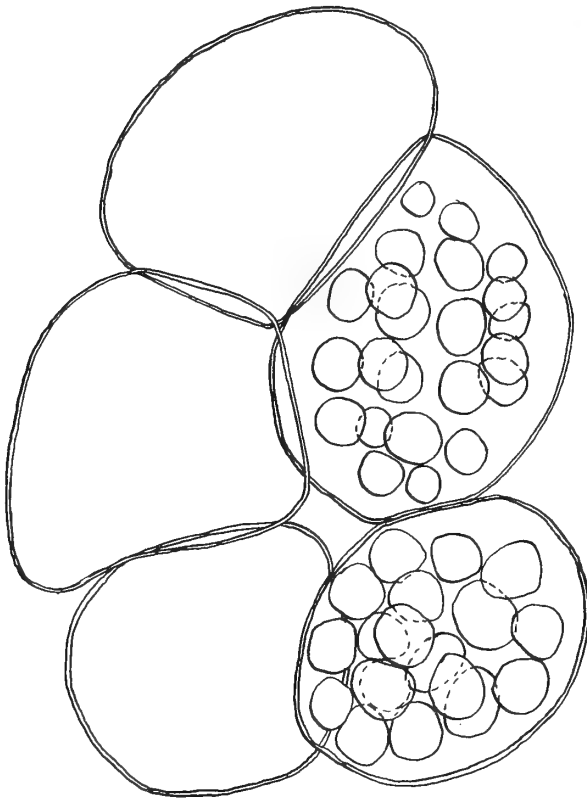


Figure 7b

Five Capsules from the Egg Mass of *Melibe leonina*

*Onchidoris bilamellata*, Plate 28, Figure 9

The adults appear gregarious, laying preferentially where other *Onchidoris bilamellata* are already present – in the field the site is usually a barnacle-covered rock where adults are common. There was no apparent difference between egg masses laid by the usual dark-coloured adult and the occasional albino or light-coloured one. The egg masses were extremely common in winter only. They are usually laid in an irregular curve and the ribbon flares out at the longer free edge (as photographed by O'DONOGHUE & O'DONOGHUE, 1922). The ribbon is about 0.20 cm thick and eggs occupy the central 0.15 cm. Its length is commonly around 3 cm and width is 0.70 to 1.0 cm. It is sometimes possible to detect the egg string in the field, but due to the extreme crowding of capsules this is not easy. Some larger capsules contained two eggs, but these were not as large as O'DONOGHUE & O'DONOGHUE measured (140 to 180 $\mu$  by 230 to 260 $\mu$ ). The size of capsules with only 1 egg agreed with the O'DONOGHUES' measurements, but most of the egg masses used by these

authors were larger than those of the present study. In the majority of masses, capsules with 1 to 2 eggs prevailed, but in some, all capsules had only 1 egg; in a very few a high proportion of capsules had 3 eggs.

*Onchidoris muricata*, Text figure 8; Plate 28, Figure 10

The small egg masses of this species were laid in the aquarium. The ribbon was relatively thick (0.1 cm) and stood erect although it sloped inwards due to the shortness of the free edge relative to the attached one. The coil was quite wide, varying from 1.25 to 2.50 whorls, the

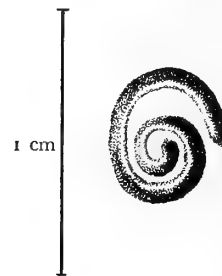


Figure 8

Egg Mass of *Onchidoris muricata*

largest mass being 0.5 cm in basal diameter. The free edge of the ribbon is transparent and the capsules are irregularly spaced, being 2 deep across the thickness of the ribbon.

*Rostanga pulchra*, Text figure 9; Plate 28, Figure 11

The vermilion or orange coils of this species' egg masses are found on or near the red food sponge, *Ophlitaspongia*, of the adults. They were found mainly during the summer months, none earlier than March, which is at variance with the year round occurrence mentioned by RICKETTS

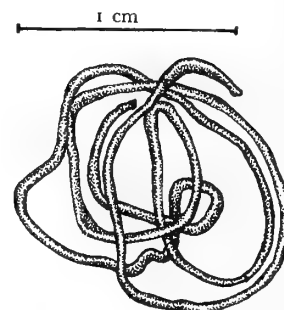


Figure 9

Egg Mass of *Rostanga pulchra*

& CALVIN (1962) in the region between San Diego and Monterey Bay. This difference is probably due to a minimum temperature requirement only attained at Friday Harbor in the summertime. The ribbon is so thick and narrow that it appears almost cylindrical and the many-whorled form of the mass (usually much neater than the one figured) is similar to that described for *Rostanga arbutus* in the Iranian Gulf (THORSON, 1940). As in this species, the egg mass grows paler with age as the red colour fades within the digestive glands of the veligers. On hatching these retain a pink colouration. The total diameter of an average coil – almost circular in disposition – is 1.25 by 1.25 cm, while ribbon width is 0.08 to 0.09 cm. The capsules are not in contact with each other, are rounded and extremely thick-walled. Most contain a single egg.

*Triopha carpenteri*, Plate 28, Figure 12

Egg masses were laid in the laboratory only between April and June although specimens had been kept at all other times of year. The white or cream ribbon is laid in a loose coil and its wavy free edge is considerably longer than the attached one. The egg string is very obvious causing a striated appearance as in *Haminoea*. The ribbon is about 1.4 cm wide. Capsules are smooth-walled and may contain 1 or 2 eggs, those with 2 being larger and more oval, some being pointed at one end. Capsules with only 1 egg are more numerous, but in a few egg masses capsules with from 5 to 7 eggs were frequent.

Egg Masses of Type B

Type B egg masses consist of three main parts, firstly a capsule-free jelly sheet (Text figures 10 b, 11 c, 15, 17 a, 18 b: js) which is usually attached to the substratum and along its free edge bears a cylindrical cord-like area (cf) containing the egg string (Text figure 11 c: es). The egg string may double to and fro (denoted here as secondary twisting) and is always crowded with capsules in contact with each other and often joining along at least part of their walls. Type B egg masses are less homogeneous than those of Type A since the relative lengths and widths of the three component parts vary widely between species and affect the general appearance considerably. The simplest form of Type B egg mass is that of *Coryphella ?rufibranchialis* (Text fig. 13 b) and *Olea hansineensis* in which the jelly-free sheet is very narrow, attached to the substratum (if flat) in a close coil and the eggstring lies untwisted in the cylindrical free edge of the mass. A more complex form is represented by *Coryphella fusca* (Text figure 12 a), *Hermisenda crassicornis* (Text figure 4 a) and *Dirona aurantia* – the egg masses of these are similar except that

the egg string is secondarily twisted. Greater degrees of complication in appearance are also common. Where the capsule-filled area of the free edge is much longer than the capsule-free attaching sheet, the latter is usually relatively wider, allowing the free edge to double to and fro upon itself. This makes the egg mass appear much wider and more complex, also the eggs are raised further above the substratum, probably allowing a better water circulation. The egg masses of *Aeolidia papillosa* (Text figure 10 a, b), *Dendronotus frondosus* (Text figure 15) and *Tritionia exulans* (Text figures 18 a, b) represent a series within which these characteristics are progressively more marked. In the most extreme cases of disparity in length between the shorter capsule-free edge of the mass and the other, opposite, capsule-filled edge, the egg mass may of necessity become tangled into a ball as in *Dendronotus iris* and *Armina californica* (Text figure 11 a). It is then attached to the substratum by one or more mucous strings, resembling the method of attachment of egg masses of Type C. Another example of a free coil attached by mucous strings, is the egg mass of *Cumanotus beaumonti* (Text figure 14). Here the egg string is not secondarily twisted and there is no attaching jelly-sheet, so that the appearance is very simple.

*Aeolidia papillosa*, Text figs. 10 a, b, c, d; Plate 29, Fig. 13

This species lays a large untidy pink or white coil, frequently attached to *Zostera* and about 6.0 by 3.50 cm in diameter. The capsules are extremely crowded and

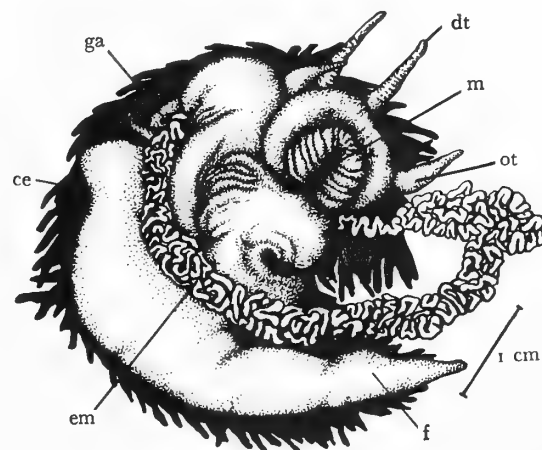


Figure 10 a

Ventral View of *Aeolidia papillosa* laying an Egg Mass

- |                      |                       |
|----------------------|-----------------------|
| ce – cerata          | f – foot              |
| dt – dorsal tentacle | ga – genital aperture |
| em – egg mass        | m – mouth             |
|                      | ot – oral tentacle    |

thin-walled, thus are often crumpled and always pushed out of shape. The capsule walls often appear pinched together at one end (Text figure 10d). The number of

in a few capsules) but another mass may have 10 to 15 eggs per capsule throughout and no capsules with as few as 6. O'DONOGHUE & O'DONOGHUE (1922) described *Aeolidia* egg masses with smaller capsules containing 1 to 3 eggs. As the egg develops into a morula, the cells protrude so that it is not smoothly spherical (Text figure 10c).

*Armina californica*, Text figs. 11 a, b, c; Plate 29, Fig. 14  
The dingy cream egg mass is laid in an untidy bundle of about 3.0 to 5.0 cm diameter. It is attached only by one

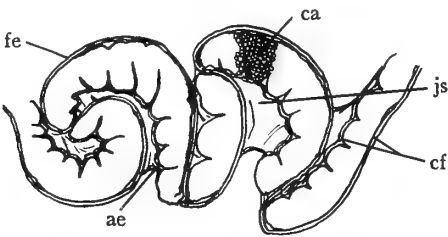


Figure 10b

Small Portion of the Egg Mass of *Aeolidia papillosa*  
ae - attached edge of egg mass    cf - capsule-filled area  
ca - capsules    fe - free edge of egg mass  
js - capsule-free jelly sheet

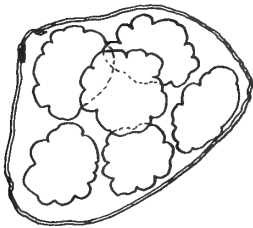


Figure 10c

One Capsule containing Six Developing Eggs of *Aeolidia papillosa*



Figure 10d

Small Area of a Capsule Wall of *Aeolidia papillosa*

eggs per capsule is rather variable, but usually fairly consistent within one egg mass. Thus in one egg mass, 6 is a common number of eggs per capsule (less may occur

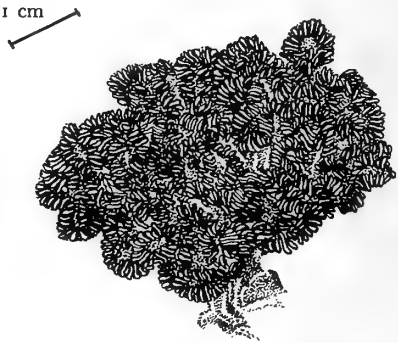


Figure 11a

Egg Mass of *Armina californica*

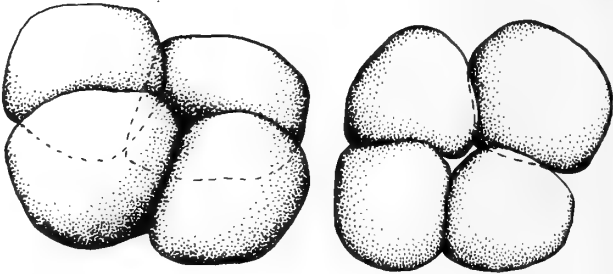


Figure 11b

Developing Eggs of *Armina californica* - at 4-cell stage

or more mucous strings from the ends of the ribbon. These may be secured by burrowing into the substratum as is the case with Type C egg masses. The capsule-free part of the egg mass is much wider and shorter than the outermost, capsule-filled part, which gives the mass its colour and lies in folds, obscuring the capsule-free jelly sheet. The egg string is secondarily twisted, looping to and fro and occasionally spiralling within the outer part

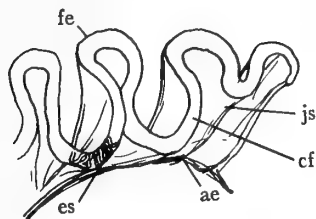


Figure 11 c

Small Portion of the Egg Mass of *Armina californica*

ae - attached edge of egg mass    es - egg string  
cf - capsule-filled area    fe - free edge of egg mass  
js - capsule-free jelly sheet

of the ribbon. In the earliest part of the egg mass, capsules are sometimes scattered down to the base of the jelly sheet (normally capsule-free), but in later areas the capsules are confined to the outer edge of the mass as in other Type B masses. At the terminal end of the mass there is sometimes a short portion without capsules, presumably because no more were available. The capsules are large, rounded and thin-walled, usually containing 12 to 15 yellowish eggs.

*Coryphella fusca*, Text figures 12 a, b; Plate 29, Figure 15

This species lays a pale pink, evenly coiled egg mass, in which the capsule-filled area is closely attached to the substratum by a narrow capsule-free sheet. The egg string

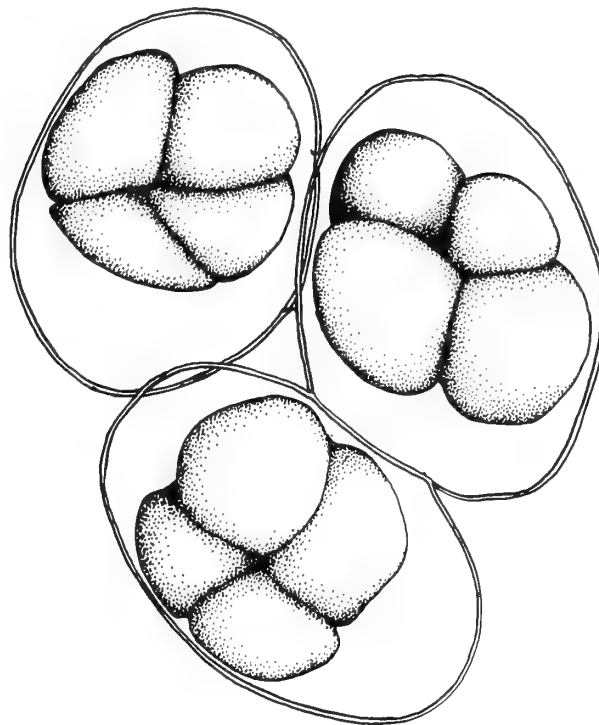


Figure 12 b

Three Capsules of *Coryphella fusca* with Eggs at 4-Cell Stage



Figure 12 a

Egg Mass of *Coryphella fusca*

(drawn from the attached edge - the transparent jelly enclosing and attaching the egg string has not been shown)

is very evenly folded within the free edge of the mass and its diameter is rather constant throughout, constrictions or empty areas being rare, unlike some other species' egg masses e. g. *Hermisenda crassicornis*. The mass presents a very neat appearance. The capsule walls are quite stout and adjacent ones sometimes join (Text figure 12 b). Each oval capsule contains 1 to 2 brownish-yellow eggs.

*Coryphella ?rufibranchialis*, Text figures 13 a, b; Plate 29, Figure 16

(The identification of this species has caused some confusion as it also has characteristics in common with *Coryphella trilineata* and *C. lineata*. The name suggested is following the conclusions of E. and E. Marcus on their examination of the animal.) The egg masses are found intertidally at low water, frequently in groups on rocks or weed, and they also occur on floats. In aquaria adults frequently laid eggs on the surface film, in undisturbed conditions. The white egg mass is laid in an extremely neat coil, looking like a watch-spring just over 1 cm in diameter. The capsule-free attaching sheet is narrower than the capsule-filled area. The egg string is not secondarily twisted and contains somewhat rounded capsules, 4 or 5 deep. Each has a thick, smooth wall and contains one almost spherical egg.

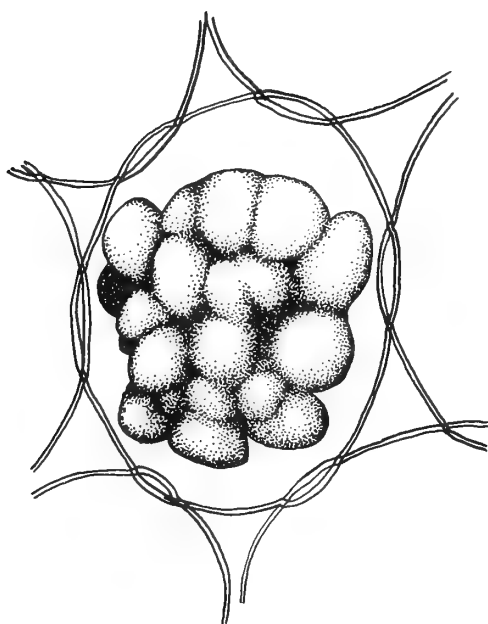


Figure 13 a

One Capsule, and Parts of Surrounding Capsules of  
*Coryphella rufibranchialis*

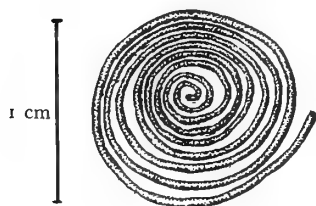


Figure 13 b

Egg Mass of *Coryphella rufibranchialis*

*Cumanotus beaumonti*, Text figure 14; Plate 30, Figure 17

This species has not been recorded previously from the North-East Pacific region and both it and its egg mass are quite distinctive. The egg mass is pale pink when first laid and becomes paler with age. It consists of a cylindrical cord containing an untwisted egg string, and there is no capsule-free sheet to attach it. Instead the mass is attached by a mucous string. The coiled mass comprises a series of parallel loops of similar diameter, so that it looks like a spring. The large oval capsules are spaced out and are thin-walled, usually becoming pushed out of shape when they do touch. They contain a variable number of eggs (4 to 14). As each egg develops to a morula the cells can



Figure 14

Egg Mass of *Cumanotus beaumonti*

be clearly distinguished and stick out slightly, but not so markedly as those of *Aeolidia* (Text figure 10 c).

*Dendronotus frondosus*, Text figure 15; Plate 30, Figure 18

This species lays an untidy coil varying from pale to dark pink. Generally the mass is quite small in diameter, although that shown in Text figure 15 consists of a shorter ribbon than is customary. The capsule-free attaching sheet is often folded at the base and thus appears shorter than it is. The capsules are in contact and sometimes joined. They are rather rounded with thin walls which are usually creased. Each capsule contains one egg.

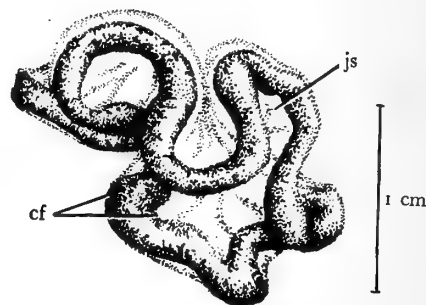


Figure 15

Egg Mass of *Dendronotus frondosus*

cf - capsule-filled area      js - capsule-free jelly sheet

*Dendronotus iris*, Plate 30, Figure 19

Only one specimen has been observed laying eggs and it laid a large rounded bundle of about 5 to 6 cm diameter. This was pure white and attached to the aquarium wall by mucous strings. The width of the capsule-free sheet relative to the outer, capsule-filled part of the mass was great and it was also much shorter than the capsule-filled region.



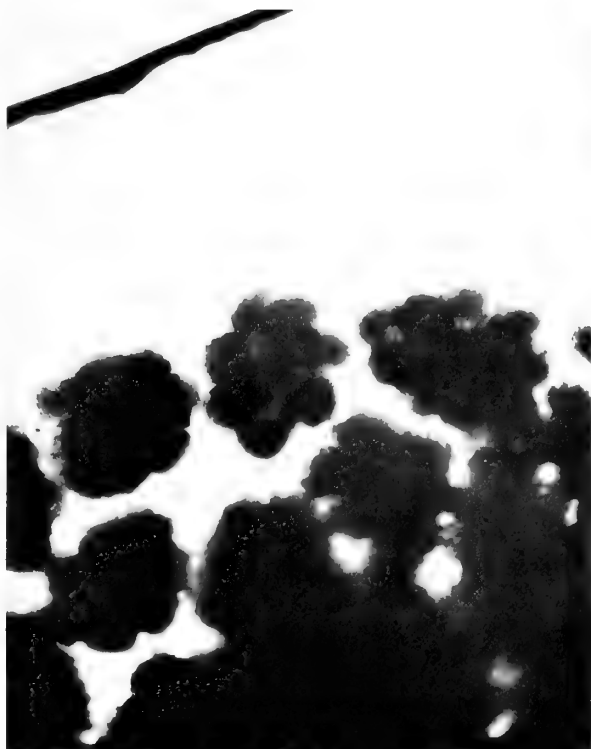


Figure 13: Egg Mass of *Aeolidia papillosa*



Figure 14: Egg Mass of *Armina californica*



Figure 15: Egg Mass of *Coryphella fusca*

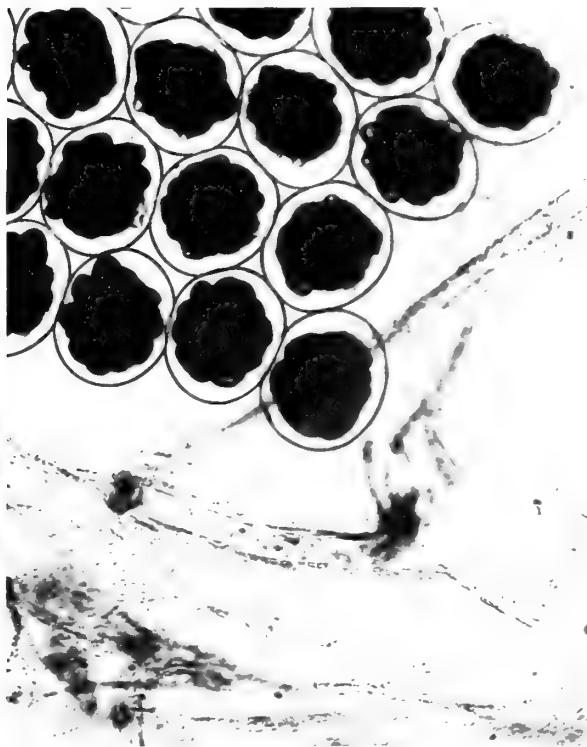


Figure 16: Egg Mass of *Coryphella rufibranchialis*



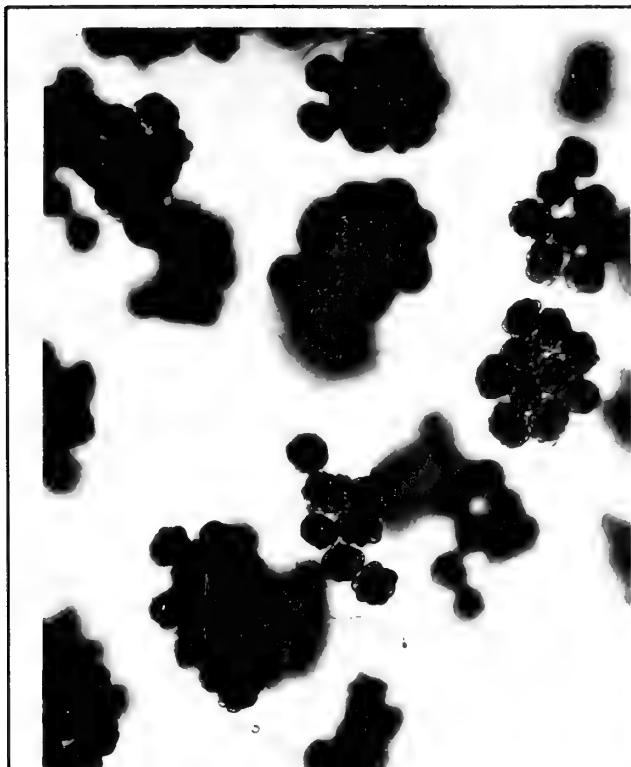


Figure 17: Egg Mass of *Cumanotus beaumonti*

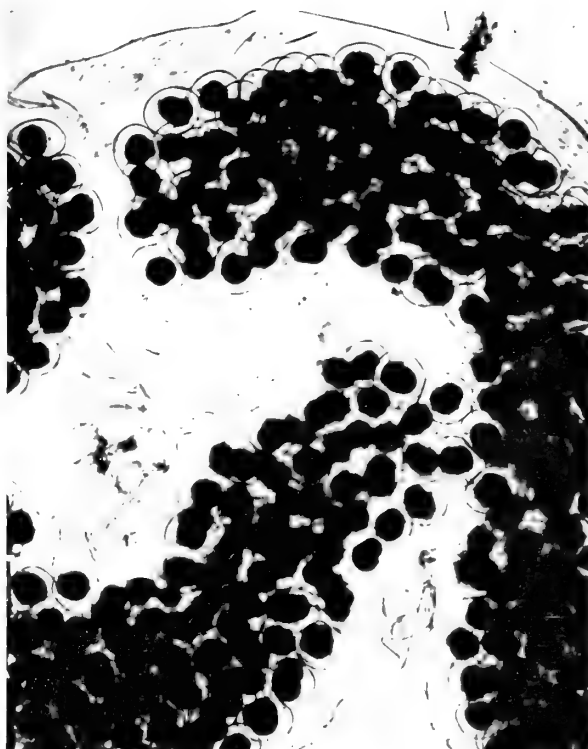


Figure 18: Egg Mass of *Dendronotus frondosus*



Figure 19: Egg Mass of *Dendronotus iris*



Figure 20: Egg Mass of *Dirona albolineata*





Figure 21: Egg Mass of *Dirona aurantia*



Figure 22: Egg Mass of *Hermissenda crassicornis*



Figure 23: Egg Mass of *Olea hansineensis*

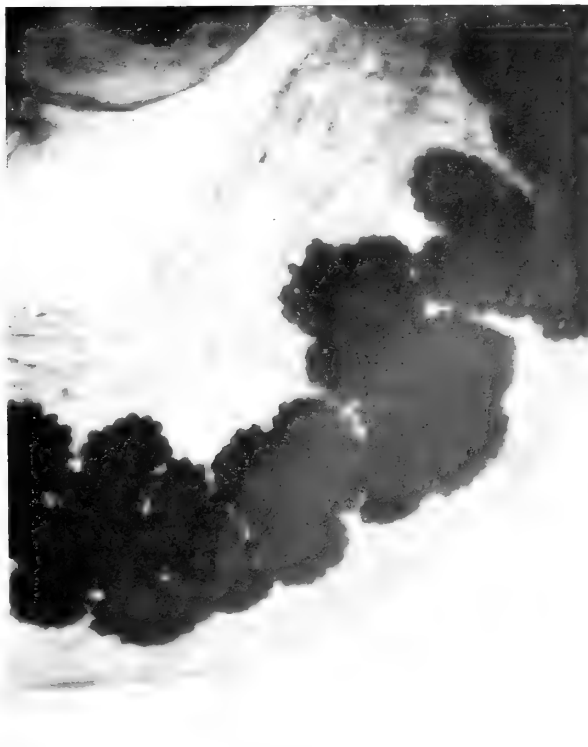


Figure 24: Egg Mass of *Tritonia exsulans*



Thus the mass automatically formed a bundle as in *Armina*. The large round capsules were arranged neatly, from 3 to 5 overlapping capsules, crossing the capsule-filled area in rather regular rows. Large numbers of eggs – more than have been observed in other species of the genus – clump together within each capsule, rarely touching its walls. The capsule walls are a little stouter than those of other dendronotid species and although adjacent walls may be slightly flattened against one another, they are rarely creased. In other dendronotids creasing is very frequent or universal amongst the thin-walled capsules.

*Dirona albolineata*, Text figure 16; Plate 30, Figure 20

The egg mass of this species is untidy in appearance and superficially similar to that of *Aeolidia*. The secondarily twisted egg string is enclosed in striated jelly in which the apparent striations are caused by greenish bodies on its surface (Text figure 16, insert). The mass has been well described by O'DONOGHUE & O'DONOGHUE (1922) in whose specimens capsules were larger ( $390\mu$

by  $260\mu$  to  $520\mu$  by  $350\mu$ ) and number of eggs per capsule (17 to 27) higher. In the present masses the capsules were in contact and were smooth-walled, each being oval and containing only 8 to 12 eggs per capsule.

*Dirona aurantia*, Text figures 17 a, b; Plate 31, Figure 21

The salmon-pink egg mass of this species is laid in a loose coil (HURST, 1966), characterized by its small size relative to that of the parent. Its general appearance recalls that of *Coryphella fusca*, but it is much less neat and

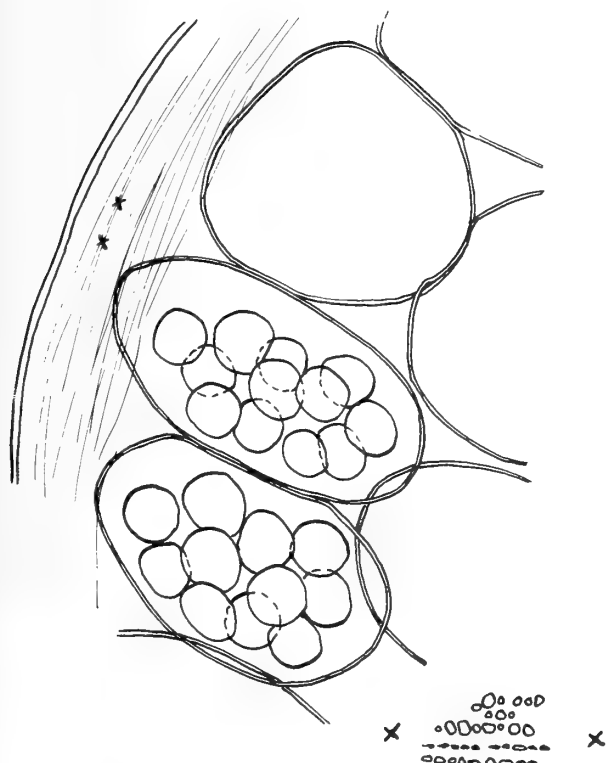


Figure 16

Several Capsules and Surrounding Jelly from the Egg Mass of *Dirona albolineata* with Detail (x-x insert) of Markings on the Jelly



Figure 17 a

Small Portion of the Egg Mass of *Dirona aurantia*  
 ae – attached edge of egg mass    cf – capsule-filled area  
 ca – capsule    fe – free edge of egg mass  
 js – capsule-free jelly sheet

regular, particularly in the secondary twisting of the egg string. The outer part of the jelly is striated, and encloses the narrow egg string, which is frequently interrupted by areas without capsules. The capsules are neatly and closely arranged, each being oval and sometimes partially collapsed. Each contains 1, 2, 3 or up to 6 eggs per capsule in a number of specimens examined. Capsule and egg size do

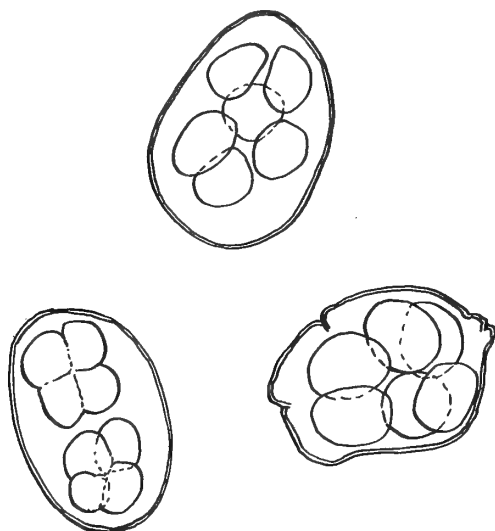


Figure 17b

Three Capsules from Three Different Egg Masses of *Dirona aurantia*

not vary in direct proportion to the number of eggs per capsule. The eggs are rounded, smooth and brownish, reaching the 2-cell stage some 24 hours after laying.

*Hermisenda crassicornis*, Text figure 4 a; Plate 31, Fig. 22

The masses of this species are common on blades of *Zostera*. The egg mass is a flat pink coil (when laid on a plane surface) similar to those of *Coryphella fusca* and *Dirona aurantia*, but generally laid in a tighter coil than either. The jelly has longitudinal striations and some slight sculpturing and encloses a secondarily twisted egg string with larger, more irregular twistings than in *C. fusca* (Text figure 12 a). There are frequent constrictions in the egg string, so that it looks like a series of pink sausages raised above the substratum in loops, due to the fairly wide capsule-free attaching jelly sheet. The mass has been described and photographed by O'DONOGHUE & O'DONOGHUE (1922) and capsule sizes agree with those of the present account. The smooth, oval capsule walls and enclosed round eggs are pinkish, becoming more yellow with age. In most masses there is one egg per capsule but in some 2 per capsule is also frequent, while in masses from exceptionally large adults 3 to 4 eggs per capsule also occur.

*Olea hansineensis*, Plate 31, Figure 23

The masses are found in proximity to those of *Haminoea* and probably to those of *Chelidonura*, on the eggs of which adult *Olea* feed. This species, like most sacoglossans, lays a simple, very close coil in which the attaching sheet is very narrow and the egg string not

secondarily twisted. The small white mass thus appears flush with the substratum and usually consists of 3 to 6 turns. The capsule walls are smooth and thin, in contact with each other but not squashed together.

*Tritonia exsulans*, Text figs. 18 a, b, c, d; Plate 31, Fig. 24

The cream egg mass of *Tritonia* is laid in a long straggling string, randomly twisted or straight and often more than 70 cm long. The colourless capsule-free sheet is rather wide and its attaching edge is white and thickened (Text figure 18 c). The sheet is not folded except at its

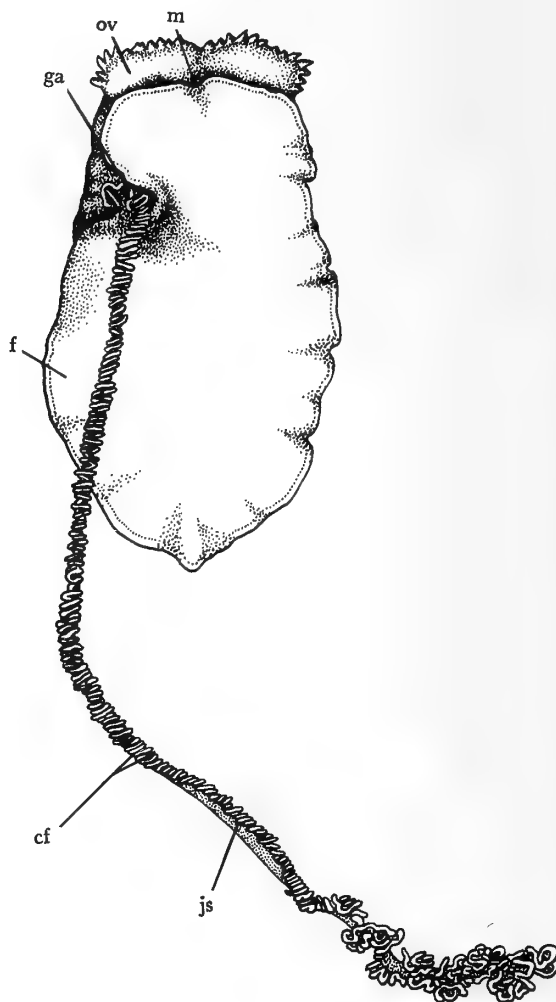


Figure 18a

Ventral View of *Tritonia exsulans* laying an Egg Mass

outer edge where it is considerably longer and thrown into folds as a consequence (Text figures 18 b, d). At





Figure 18 b

Small Portion of the Egg Mass of *Tritonia exulans*

- |                                |                               |
|--------------------------------|-------------------------------|
| ae - attached edge of egg mass | fe - free edge of egg mass    |
| ca - capsule                   | ga - genital aperture         |
| cf - capsule-filled area       | js - capsule-free jelly sheet |
| f - foot                       | m - mouth                     |
|                                | ov - oral veil                |

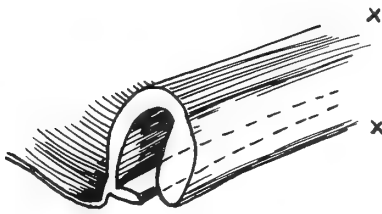


Figure 18c

Detail of the Attached Edge of the Egg Mass of *Tritonia exsulans*

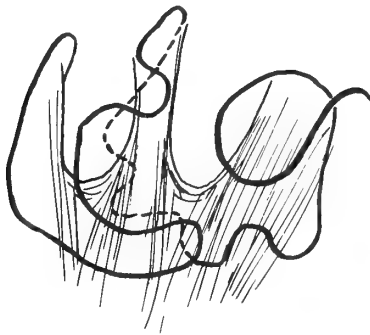


Figure 18d

Diagrammatic Representation of the Coils of the Capsule-Filled Area of the Portion of the Egg Mass shown in Figure 18b

the outer edge is the egg string which may twist in a regular or irregular fashion, greatly affecting the appearance of the egg mass. Sometimes both occur in one mass, as in Text figure 18a. In most masses the folding of the whole outer part of the ribbon and the egg string within it is irregular, as in the earliest part of the mass figured. The large capsules are usually polygonal due to flattening of their sides by contact between adjacent capsules. Each contains many small eggs.

#### Egg Masses of Type C

Egg masses of this type laid by cephalaspids, are usually attached by burrowing into the sand with the jelly string from the apex of the mass, as described by GUIART (1901) in *Philine* and FRETTER & GRAHAM (1954) in *Acteon*. The animals whose egg masses are described here also burrow and usually attach their jelly-bags similarly.

##### *Aglaja diomedea*

The ovoid egg masses are found in large numbers in spring and summer, attached to weed or below the sand's surface, the mass itself not being buried. The sandy colour provides good camouflage. The egg string is obvious and

some capsules are mutually attached by a narrow string between their respective walls, running from the narrower end of the oval shape. Information on *Aglaja* in Table 5 refers to local animals, but some smaller specimens from a more distant area (within the same region) laid smaller masses (0.3 by 0.4 cm) with no obvious egg string. The specimens may represent another species or subspecies. Capsule size lay within the range of that of undoubted *Aglaja diomedea* but veliger size did not and the veliger shells were distinguishable (discussed further below). The adult animals showed some slight external differences from local specimens.

##### *Chelidonura phocae*

This animal lays a cylindrical egg mass with rounded ends, in which the coils of the egg string are very obvious. The colour is white and the capsules are egg shaped with stout smooth walls. Each contains a slightly oval, centrally placed single egg.

##### *Gastropteron pacificum*

The egg mass is almost globular and of clear jelly. It contains widely separated rounded capsules containing spherical pink eggs. The smooth-walled capsules each have a short string-like protrusion from one point on their surfaces and this does not appear to be attached elsewhere. As the eggs develop to form a ball of cells, the pink colour becomes concentrated and at one side of it is a group of yellowish cells, the whole being surrounded by a narrow layer of greenish cells.

#### Egg Masses of Type D

The small, often sac-like egg masses of this group are not morphologically uniform and are considered together for convenience.

##### *Catriona aurantia*, Text figure 19; Plate 32, Figure 25

The egg mass is whitish or colourless and is a small bag, gathered together at one end which is attached to a solid surface. The oval capsules within it are smooth-walled and closely packed, but are not squashed together.

##### *Cratena albocrusta*

In the laboratory, the egg masses were attached by one side to the surface film of the water, or occasionally to the aquarium wall. It is unlikely that the egg mass would be attached to the surface film in the natural habitat. Each pinkish egg mass was less than 1 cm long and was sausage shaped. The capsules are closely arranged but not pressed out of shape. They are oval and often joined together by a small region of their walls, frequently at the narrow end of the oval.

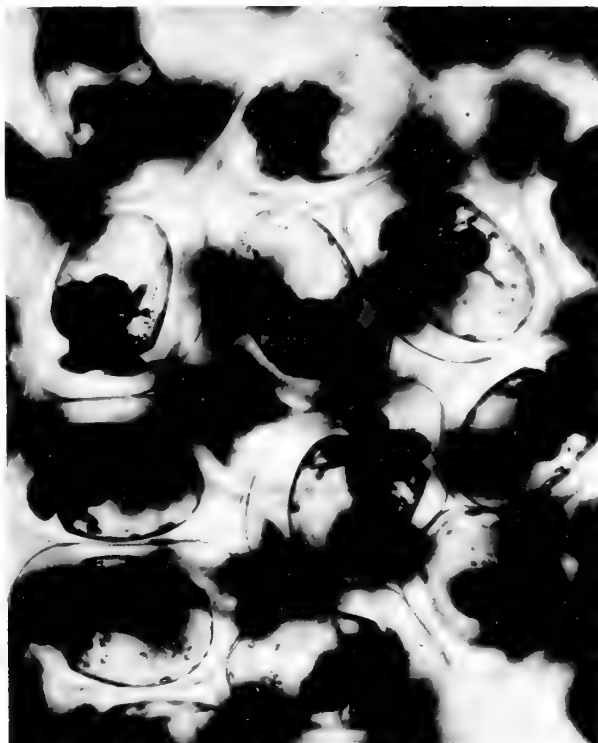


Figure 25: Egg Mass of *Catriona aurantia*



Figure 26: Egg Mass of *Eubbranchus olivaceus*

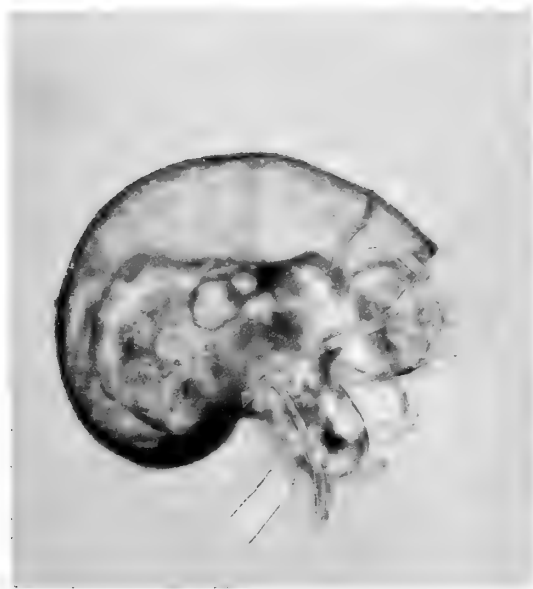


Figure 27: Veliger of *Acanthodoris brunnea*

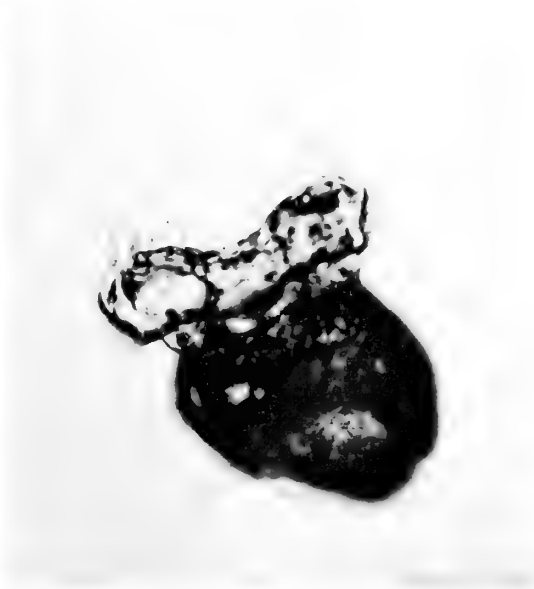


Figure 28: Veliger of *Acanthodoris hudsoni*



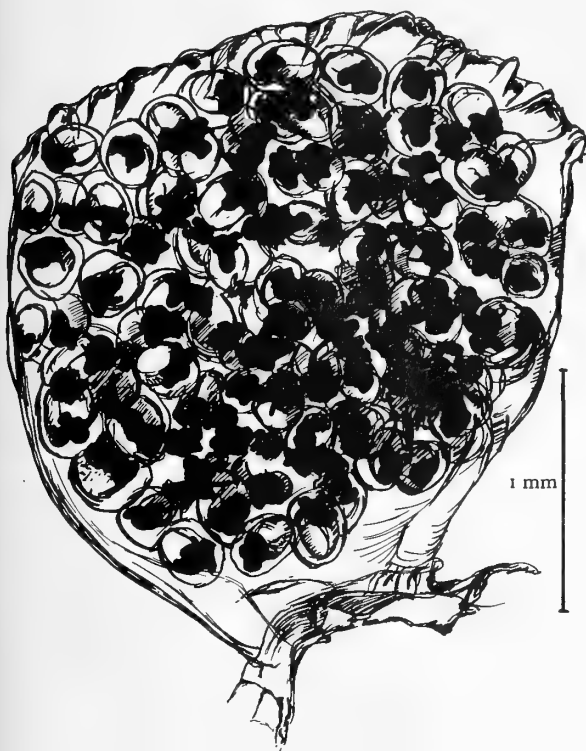


Figure 19

Egg Mass of *Catriona aurantia**Eubranchius olivaceus*, Text figure 20; Plate 32, Figure 26

The rather uniform and characteristic masses are found on the hydroid prey of the adults, present specimens lay-

1 mm

Figure 20

Egg Mass of *Eubranchius olivaceus*

ing eggs earlier than those of O'DONOGHUE & O'DONOGHUE (1922). The egg mass is like a small section of a Type B mass, without secondary twisting of the egg string. Eggs occupy a crescent-shaped area and the mass is attached by a small area at the base of a capsule-free attaching sheet. The whole is approximately triangular, with a convex free edge. The oval capsules are closely arranged and each contains a single egg. Their size overlaps with that measured by the O'DONOGHUES, being a little larger. The description given by these authors otherwise agrees with present observations.

### VELIGER SHELLS

To some extent it is possible to identify the veligers of opisthobranchs by examination of their shells, especially when these are freshly empty. As THOMPSON (1961) has noted, the shells are of two main types: firstly coiled, uninflated shells of  $\frac{3}{4}$  to 1 whorl only; secondly somewhat egg-shaped, inflated shells. All are typically sinistral as mentioned by FRETTER & GRAHAM (1962). THORSON (1946) also recognized a third group of cap-like shells,

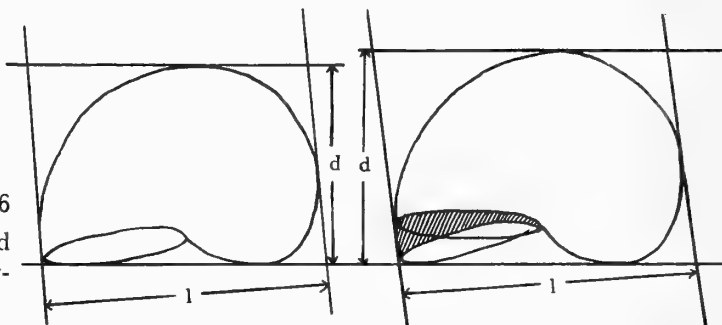


Figure 21

Length and Depth Measurements of a Veliger Shell of Type 1  
a - before Growth; b - after Growth. The Effect of Growth is greater in Depth Measurement than in Length Measurement.

which is not here regarded as a separate type. It has been observed that damaged shells of Type 1 and less inflated shells of Type 2 may be cap-like, also prematurely hatched veligers of some species e. g. *Dendronotus* may have cap-shaped cells (Text figure 30: [sh]) - as also occurs in *Tritonia* (THOMPSON, 1961). The veligers mentioned in this paper have thus been divided into Types 1 and 2, following THOMPSON.

The average measurements given (Tables 9, 11) are derived from standard samples of empty shells, each collected from a healthy population of seemingly normal veligers hatched in the laboratory. In some cases the

Table 1  
Characteristics of the Egg Masses of Species of Type A

	Months found											
	January	February	March	April	May	June	July	August	September	October	November	December
<i>Acanthodoris brunnea</i> :					X	X						
<i>Acanthodoris hudsoni</i> :				X	X							
<i>Acanthodoris nanaimoensis</i> :		X			X					X	X	
<i>Archidoris montereyensis</i> :	X	X	X	X	X	X				X	X	X
<i>Austrodoris odhneri</i> :				X	X	X						
<i>Diaulula sandiegensis</i> :		X	X	X	X							
<i>Haminoea virescens</i> :		X			X	X	X	X		X	X	X
<i>Melibe leonina</i> :	X	X	X	X	X	X	X	X	X	X	X	X
<i>Onchidoris bilamellata</i> :		X	X							X	X	X
<i>Onchidoris muricata</i> :	X	X	X									
<i>Rostanga pulchra</i> :			X	X	X	X				X		
<i>Triopha carpenteri</i> :				X	X	X						

Table 2  
Characteristics of the Egg Masses of Species of Type A

	Eggs per Capsule									Capsules Touching			Capsule Wall	
	1	2	3	4	5 - 7	8 - 12	12 - 15	15 - 30	30 - 60	Majority	Fairly frequent	Rarely or none	Sculptured	Smooth
<i>Acanthodoris brunnea</i> :	×											×		×
<i>Acanthodoris hudsoni</i> :	×											×		×
<i>Acanthodoris nanaimoensis</i> :	×											×		×
<i>Archidoris montereyensis</i> :	×	×	×								×		×	
<i>Austrodoris odhneri</i> :			×	×	×	×					×	×		
<i>Diaulula sandiegensis</i> :	×	×								×			×	×
<i>Haminoea virescens</i> :	×	×								×	×		×	×
<i>Melibe leonina</i> :					×	×		×			×		×	
<i>Onchidoris bilamellata</i> :	×	×	×								×		×	
<i>Onchidoris muricata</i> :	×											×	×	
<i>Rostanga pulchra</i> :	×	×								×	×		×	×
<i>Triopha carpenteri</i> :	×	×			×					×			×	

Table 1

### Characteristics of the Egg Masses of Species of Type A

[illegible]

Table 2

### Characteristics of the Egg Masses of Species of Type A

	Capsule Dimensions in $\mu$	Veliger Type	Days Taken
	. minimum maximum . ^ average of least diameter v average of greatest diameter		
	80 - 100 101 - 120 121 - 140 141 - 160 161 - 180 181 - 200 201 - 220 221 - 240 241 - 260 261 - 280 281 - 300 301 - 320 321 - 340 341 - 360 361 - 380 381 - 400 401 and up	1: uninflated 2: inflated	time to hatch appearance of veliger
.	. ^	x	9 7
.	. ^ v.	x	16 12
.	. ^ ^ v.	x	9 6
.	. v.	x	23-28 13-22
.	. <v>	x	22-33 13-16
.	. ^ ^ v.	x	22-28 17
.	. v.	x	9-18 7-12
.	.	x	8-15 7-12
.	.	> 443 . 567	
.	. ^	x	12-13 7-10
.	. ^ v.	x	7-14 4-13
.	. <v>	x	30 26
.	.	x	18 17

**Table 3**  
**Characteristics of the Egg Masses of Species of Type B**

	Months found												Colour				
	January	February	March	April	May	June	July	August	September	October	November	December	White	Cream	Yellow	Pink	Other
<i>Aeolidia papillosa</i> :	×	×										×	×			×	
<i>Armina californica</i> :	×	×			×	×		×				×	×	×			
<i>Coryphella fusca</i> :		×						×			×	×				×	
<i>Coryphella ?rufibranchialis</i> :		×	×							×			×				
<i>Cumanotus beaumonti</i> :					×								×			×	
<i>Dendronotus frondosus</i> :			×			×							×			×	
<i>Dendronotus iris</i> :						×	×						×				
<i>Dirona albolineata</i> :	×					×						×	×				
<i>Dirona aurantia</i> :	×	×	×													×	
<i>Hermisenda crassicornis</i> :		×	×		×		×	×			×	×				×	
<i>Olea hansineensis</i> :							×						×				
<i>Tritonia exsulans</i> :	×	×	×				×	×	×		×	×		×			

**Table 4**  
**Egg Capsule Dimensions of Species of Type B**

	minimum	Capsule Dimensions in $\mu$ average of least diameter
	80 81 - 100 101 - 120 121 - 140 141 - 160 161 - 180 181 - 200 201 - 220 221 - 240 241 - 260 261 - 280 281 - 300 301 - 320 321 - 340 341 - 360 361 - 380 381 - 400 391 - 420 421 - 440 441 - 460	
<i>Aeolidia papillosa:</i>	.	>
<i>Armina californica:</i>	.	>
<i>Coryphella fusca:</i>	.<	.
<i>Coryphella ?rufibranchialis:</i>	.<>	.
<i>Cumanotus beaumonti:</i>	.	>
<i>Dendronotus frondosus:</i>	.<>	.
<i>Dendronotus iris:</i>	.	>
<i>Dironea albolineata:</i>	.	>
<i>Dironea aurantia:</i>	.	.
<i>Hermisenda crassicornis:</i>	.<	.
<i>Olea hansineensis:</i>	.< >	.
<i>Tritonia exsulans:</i>	.	.



Table 3  
Characteristics of the Egg Masses of Species of Type B

Width Egg String	Attach- ment	2ndy Twis- ting	Eggs per Capsule										Veliger Type	Days Taken	
			1	2	3	4	5 - 7	8 - 12	13 - 19	20 - 30	30 - 60	1: uninflated	2: inflated	time to hatch	appearance of veliger
< 1 mm	> 1 mm	Most of length Other	Present	Not present											
X	X	X	X			X	X	X	X			X		10-24	8-15
X	X	X	X		X			X	X			X		17-23	12-15
X	X	X	X	X								X		7-8	6
X	X	X	X	X								X		23	
X	X	X	X				X	X	X			X		10	8
X	X	X	X								X		X	7-15	2-7
X	X	X	X				X	X				X			8-9
X	X	X	X			X	X	X				X		13	9-10
X	X	X	X			X	X					X		7-8	5
X	X	X	X	X								X		5-7	3
X	X	X	X								X	X		12-16	8

Table 4  
Egg Capsule Dimensions of Species of Type B

Capsule Dimensions in $\mu$	
> average of greatest diameter	maximum .
461 - 480	
481 - 500	
501 - 520	
521 - 540	
541 - 560	
561 - 580	
581 - 600	
601 - 620	
621 - 640	
641 - 660	
661 - 680	
681 - 700	
701 - 720	
721 - 740	
741 - 760	
761 - 780	
781 - 800	
801 - 820	
821 - 840	
841 - 860	
861 - 880	
881 - 900	
901 - 920	
921 - 940	
941 - 960	
961 - 980	
981 - 1000	

Table 5  
Characteristics of the Egg Masses of Species of Type C

	Months found											
	January	February	March	April	May	June	July	August	September	October	November	December
<i>Aglaja diomedea</i> :			×			×						
<i>Chelidonura phocae</i> :			×	×	×	×						
<i>Gastropteron pacificum</i> :	×	×	×		×	×						

Table 6  
Characteristics of the Egg Masses of Species of Type C

Capsule Dimensions in $\mu$												Veliger Type	Days Taken		
minimum	$\angle$ average of least diameter												1: uninflated	time to hatch	appearance of veliger
maximum	$\sphericalangle$ average of greatest diameter											2: inflated			
	- 80	81 - 100	101 - 120	121 - 140	141 - 160	161 - 180	181 - 200	201 - 220	221 - 240	241 - 260	261 - 280		281 - 300		
<i>Aglaja diomedea</i> :						$\angle$					$\sphericalangle$		$\times$		8-20 18
<i>Chelidonura phocae</i> :				$\angle$		$\sphericalangle$							$\times$		7-12 11
<i>Gastropteron pacificum</i> :							$\angle$	$\sphericalangle$					$\times$		14-15 9-10

Table 7  
Characteristics of the Egg Masses of Species of Type D

	Months found											
	January	February	March	April	May	June	July	August	September	October	November	December
<i>Catriona aurantia</i> :			×									
<i>Cratena albocrusta</i> :								×				×
<i>Eubranchius olivaceus</i> :					×		×	×				

Table 5  
Characteristics of the Egg Masses of Species of Type C

	Colour					Mass Dimensions							Egg String		Eggs per Capsule				
	White	Cream	Sandy	Pink	Other	- 0.5 mm	0.6 - 1.0 mm	1.1 - 1.5 mm	1.6 - 2.0 mm	2.1 - 2.5 mm	2.6 - 3.0 mm	3.1 - 3.5 mm	very obvious	not so	1	2	3	4	5 and up
	×	×	×				×	×	×		×		×		×	×	×	×	
				×				×	×		×		×	×	×	×	×	×	×

Table 8  
Characteristics of the Egg Masses of Species of Type D

Capsule Dimensions in $\mu$																Veliger Type	Days Taken		
minimum	maximum	$\wedge$ average of least diameter $\vee$ average of greatest diameter																	
		- 100	101 - 120	121 - 140	141 - 160	161 - 180	181 - 200	201 - 220	221 - 240	241 - 260	261 - 280	281 - 300	301 - 320	321 - 340	341 - 360	1: uninflated	2: inflated	time to hatch	appearance of veliger
<i>Catrina aurantia:</i>										$\wedge$					$\vee$		$\times$	13	5
<i>Cratena albocrusta:</i>				$\wedge$		$\vee$											$\times$	20-21	19
<i>Eubbranchus olivaceus:</i>			$\wedge$		$\vee$												$\times$	11	3

Table 7  
Characteristics of the Egg Masses of Species of Type D

	Colour					Dimensions							Eggs per Capsule		
	White	Cream	Yellow	Pink	Other	- 0.5 mm	0.6 - 1.0 mm	1.1 - 1.5 mm	1.6 - 2.0 mm	2.1 - 2.5 mm	2.6 - 3.0 mm	3.1 - 3.5 mm	1	2	3 and up
	×									×	×		×	×	×
	×			×				×		×			×	×	×

average is based on two or more samples, taken from different egg masses of a single species. In these cases variance between the samples has been examined by *f* tests (Table 10) and the results are discussed below.

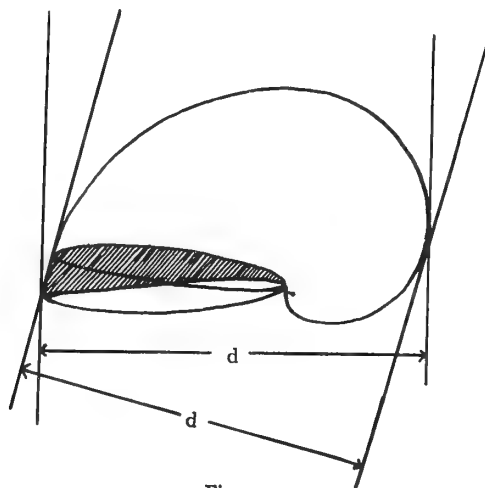


Figure 22

Length Measurement of a Veliger Shell of Type 1 with a widely flared Aperture. The Orientation of the Shell has a Considerable Effect on the Result of Measurement.

The validity of the sampling methods and size measurements is also considered in the discussion. The amount of growth occurring appeared to be negligible under laboratory conditions, as noted by THORSON (1946) in a discussion of nudibranch larvae.

The ratios of length : width : depth (Tables 9, 11) are calculated from average values and seem to be fairly constant. These ratios, in conjunction with Text figure 24 (double fold-out) describe the size and shape of the shells of individual species. The size, shape and sculptural patterns of veliger shells do not vary much intra-specifically and are characteristic of their species. The exact distribution of lines of sculpture was remarkably constant in almost all samples examined in the present study. The apparent shape varies greatly according to orientation. The figures are drawn to scale from sequences of photographs (taken from different levels of focus) of individual veliger shells and as far as possible shells were similarly oriented for each series of views (dorsal, right lateral, ventral, left lateral). This in some cases emphasizes and in others detracts from the distinctive features.

#### Veliger Shells of Type 1

Animals from 13 families (THIELE, 1931) are included, 4 of which – the Oleidae, Arminidae, Dironidae and Tethyidae (Table 9) – have not been described previously

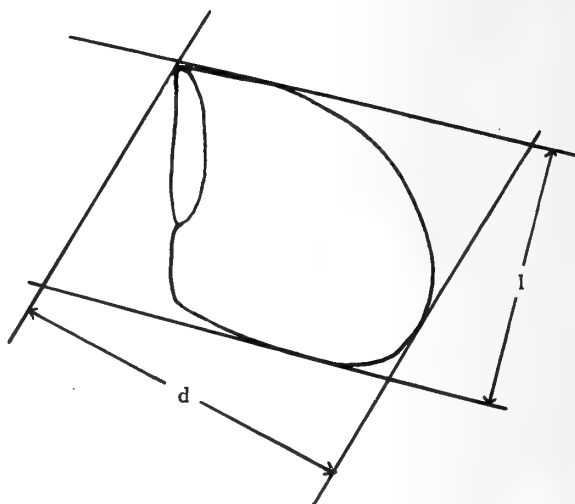
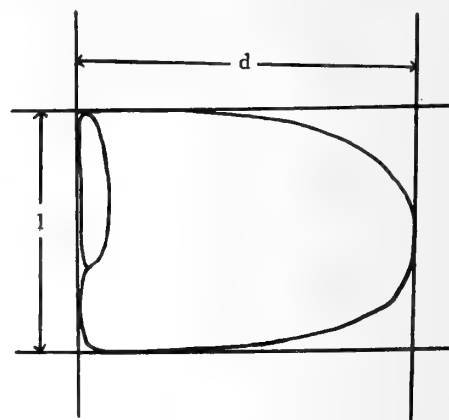


Figure 23

Length and Depth Measurements of Veliger Shells of Type 2. The Shape of the Shell Affects the Orientation of the Measure of Length and Depth.

as having veligers of this type (THOMPSON, 1961). AGERS-BORG (1921) illustrated a sac-like veliger shell of *Melibe leonina* (Tethyidae) which is atypical, but shells of a somewhat similar aberrant shape have occasionally occurred in *Melibe* veliger populations during the present study. The only other species noted here as having rather variable shell shape are *Olea hansineensis* and *Hermis-senda crassicornis*. In *Olea* a minority of shells appeared which were relatively shorter than that illustrated and in one population of *Hermis-senda* veligers misshapen shells were abundant, being longer and less steeply curved over the dorsal part of the shell. In one species, *Acanthodoris hudsoni*, all shells were fragile, and although the veligers







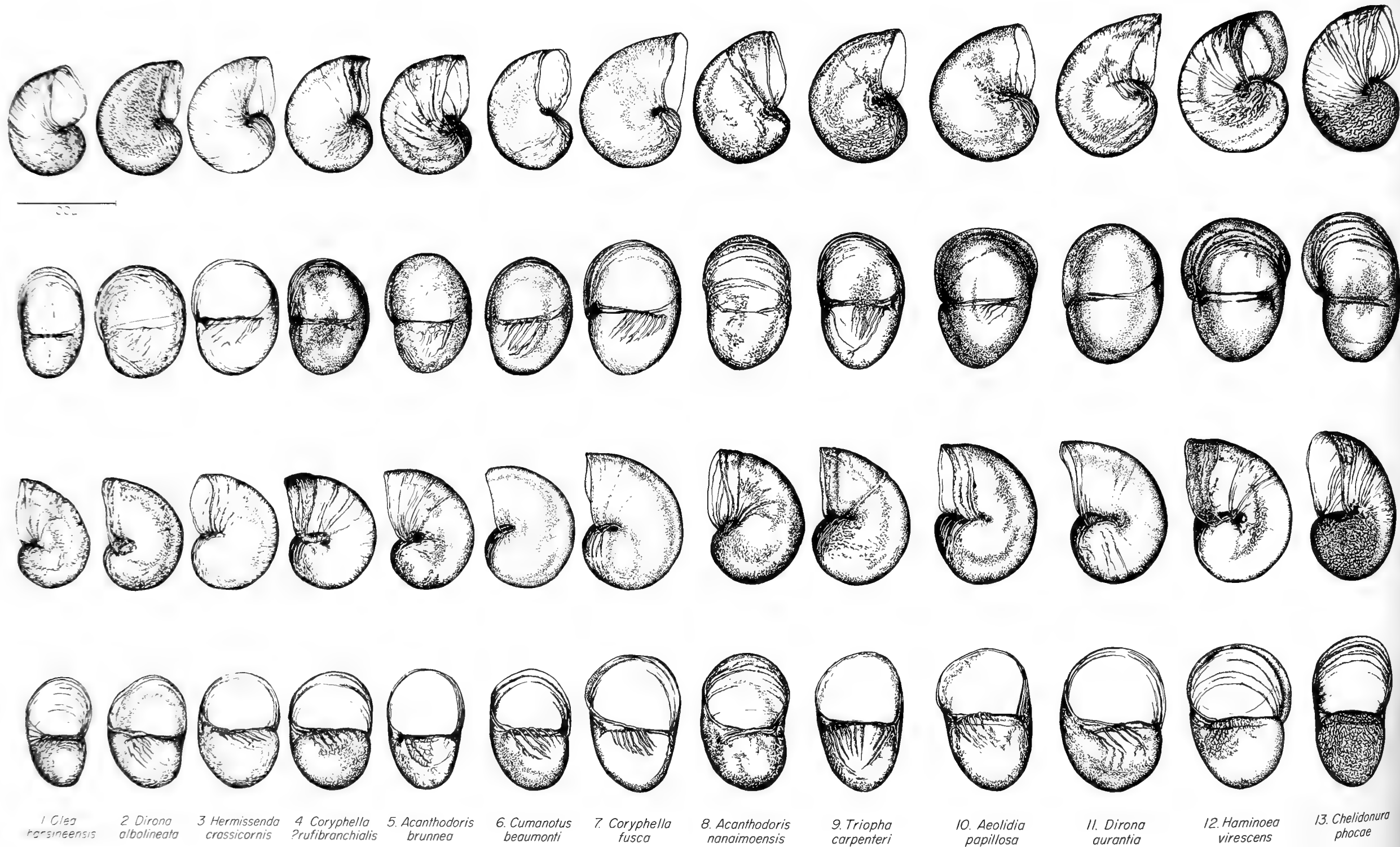


Figure 24

Comparative Drawings of Veliger Shells of Type I in Right Lateral, Dorsal, Left Lateral, and Ventral View. Each Drawing is taken from Serial Photographs and scaled to Average Size. (see length measurements in Table 9)













Figure 24

Comparative Drawings of Veliger Shells of Type I in Right Lateral, Dorsal, Left Lateral, and Ventral View. Each Drawing is taken from Serial Photographs and scaled to Average Size. (see length measurements in Table 9)



survived for several weeks, they may have been abnormal, since in some other species unhealthy egg masses produced veligers with such shells. Shells of the veligers of *Aglaja diomedea* varied in overall size, not shape, and this may represent geographical variation or presence of 2 or more closely similar species, as suggested in the description of the egg masses of *Aglaja*. Variation in this species is reflected in the *f* test (Table 10).

Differences between the shape of veliger shells of similar size include characteristics such as

- a) the length : width : depth ratio
- b) whether the rim of the shell is flared, smooth or indented
- c) the angle at which the edge of the shell bounding the shell aperture attaches to the inner part of the shell
- d) the position of its attachment
- e) the relative size of the aperture and body whorl to the rest of the shell
- f) the degree of curvature of the dorsal part of the shell.

The nature of these differences is constant between species and they can be readily distinguished with practice.

In nearly all cases the veliger shells have a slightly roughened surface, in some cases e. g. *Archidoris* (Text figure 24 [18]), markedly so. The roughness may be concentrated to form a rather characteristic pattern, as in the case of *Chelidonura* (Text figure 24 [13]), *Haminoea* (Text figure 24 [12]) and others, in which the pattern usually has a limited but constant distribution over the shell's surface. In *Gastropteron* (Text figure 24 [19]) the pattern is even more well marked and characteristic. A very common sculptural pattern is that of raised lines e. g. *Aeolidia* (Text figure 24 [10] and *Dirona* sp. (Text figure 24 [2, 11]), situated on the innermost, oldest part of the shell. Generally there are several lines arranged close together, either parallel or fanning out slightly. The number and angle of the lines varies little within a species. Occasionally only a single line is present, as in *Rostanga* (Text figure 24 [21]).

#### Veliger Shells of Type 2

Animals from 3 families (THIELE, 1931) are included (Table 11), one of which, the Flabellinidae (represented here by *Eubranchus olivaceus*), also includes animals with veligers of Type 1 considered above (*Coryphella*, *Cumanotus*). As suggested by THOMPSON (1961) and earlier, on other grounds, by WINCKWORTH (1951), the grouping of animals in this family reflects an unnatural classification. *Cumanotus* and *Coryphella*, on anatomical and larval evidence, should remain together, *Eubranchus* being separated.

Measurements of shells of Type 2, including length : width : depth ratios are indicative of the difference in shape from those of Type 1. Thus width and length were the smaller figures because of the inflation of the dorsal region. This inflation makes true measurement of the depth difficult since the angle or position of inflation is variable. Depth was thus arbitrarily taken as a measure of the longest axis other than width or length (Text figure 23 and further discussion below). The measurement of length may also be affected by inflation of the shell. Thus width is the least variable of the measurements, as for Type 1. Difficulty in accuracy and consistency of measuring methods is reflected in the standard deviations from average figures (Table 11).

The shape of the shells is shown in Text figure 25. Differences include

- a) the angle and degree of inflation
- b) evenness of curvature (which is very constant)
- c) relative size of the aperture
- d) shape of the aperture
- e) presence or absence of a lip at the aperture.

In one species, *Cratena albocrusta* (Text figure 26), the operculum [op] remained firmly attached to large numbers of empty shells [sh]. No marked sculptural patterns were present in the shells of species included here although those of *Dendronotus frondosus* (possibly *D. rufus*) were observed to have definite characteristic lines on the veliger shells (Text figure 27), possibly from uneven deposition of shell material. *Dendronotus frondosus* had the most cap-like (see above discussion) of veliger shells (Text figure 25 [5]), with the possible exception of some immature veligers (Text figure 30 and discussion below).

#### VELIGERS

As THORSON (1946) and PRUVOT-FOL (1954) have stated, the veligers of opisthobranchs are very much alike, but as THORSON indicated and as the above notes on shells prove, exact measurements and drawings make it possible to identify them to some extent. The veliger body (as opposed to the shell) is more difficult to distinguish accurately. In opisthobranchs, unlike prosobranchs (many of which have been described by LEBOUR (1937, and earlier work)), there are few veligers which have outstandingly characteristic velar or metapodial lobes.

In the present survey it was noted that all the cephalaspids—*Aglaja diomedea* (Plate 33, Figure 30), *Chelidonura phocae* (Plate 34, Figure 36), *Gastropteron pacificum* (Plate 36, Figure 42), *Haminoea virescens* (Plate 36, Figure 43) — had veligers with deeply pigmented kidneys (Text figures 28, 29: [k]). In *Aglaja diomedea* the colour was usually black, occasionally purple; *Chelidonura phocae* and *Gastropteron pacificum* veligers had black kid-

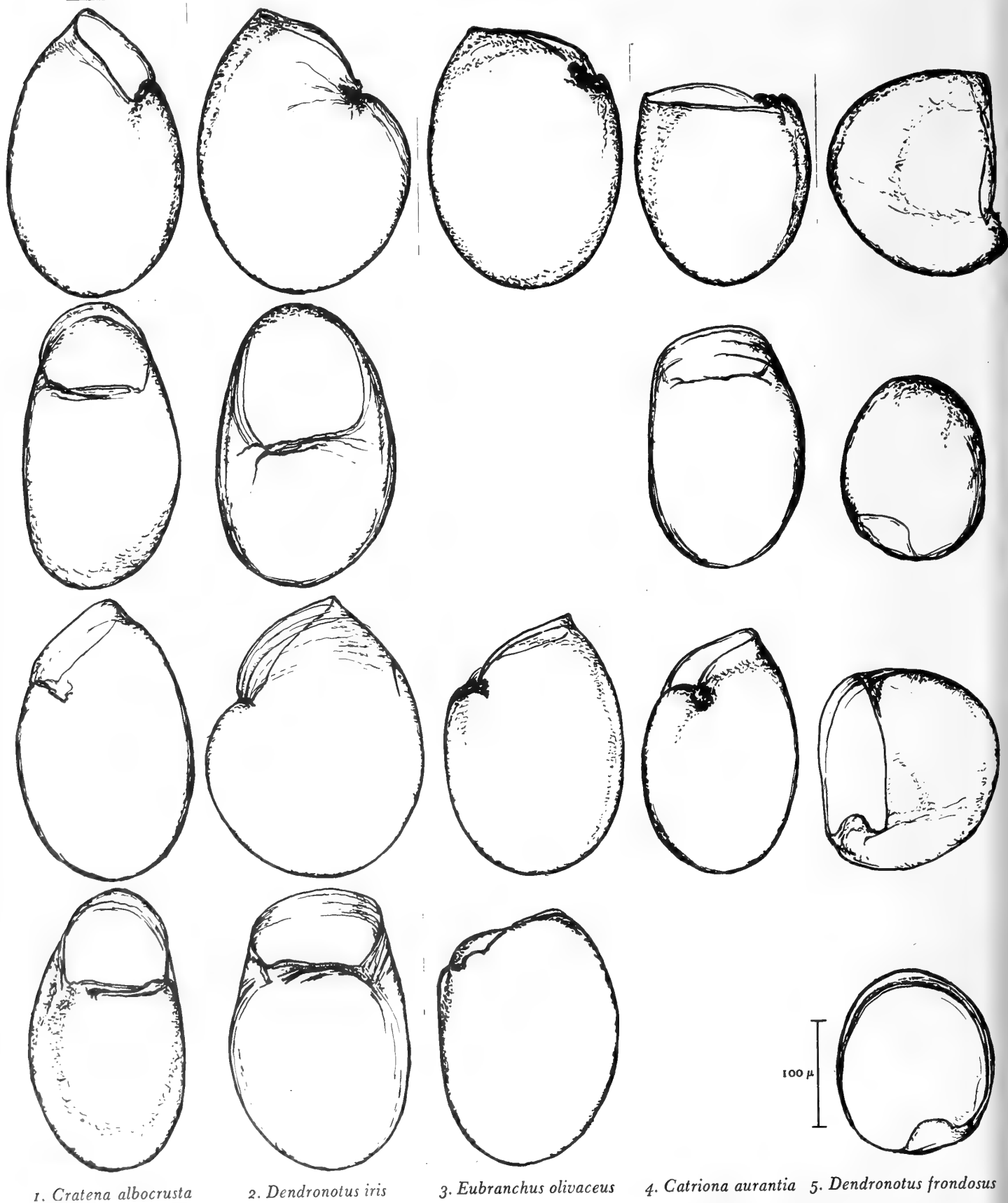


Figure 25

Comparative Drawings of Veliger Shells of Type 2 in Right Lateral, Dorsal, Left Lateral and Ventral View. Each Drawing is taken from Serial Photographs and scaled to Average Size. (see depth measurements in Table 11).



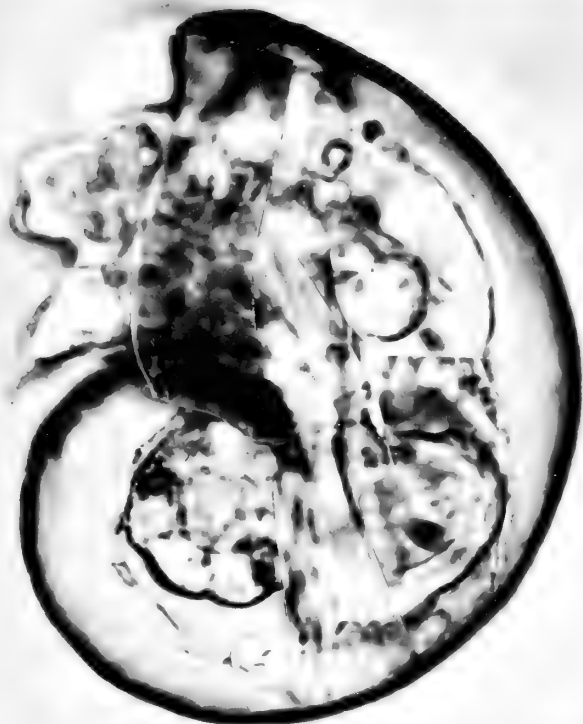


Figure 29: Veliger of *Aeolidia papillosa*

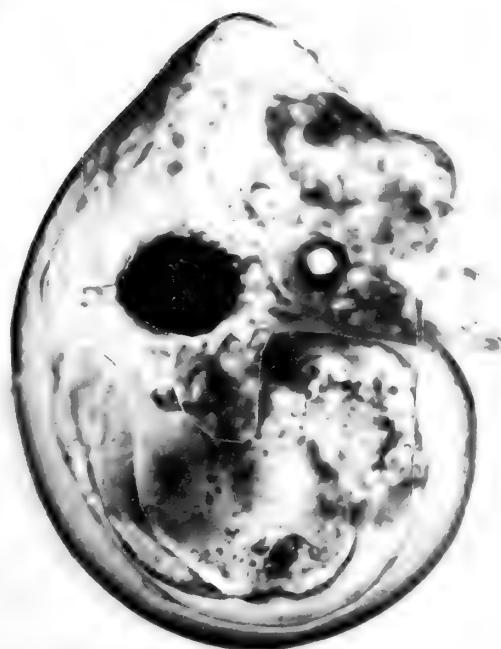


Figure 30: Veliger of *Aglaja diomedea*



Figure 31: Veliger of *Austrodoris odhneri*

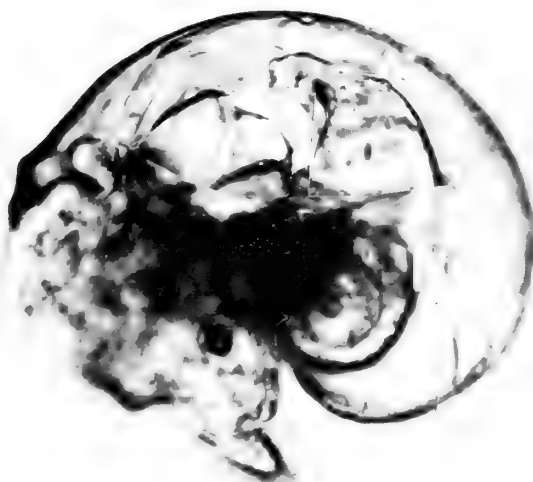


Figure 32: Veliger of *Austrodoris odhneri*



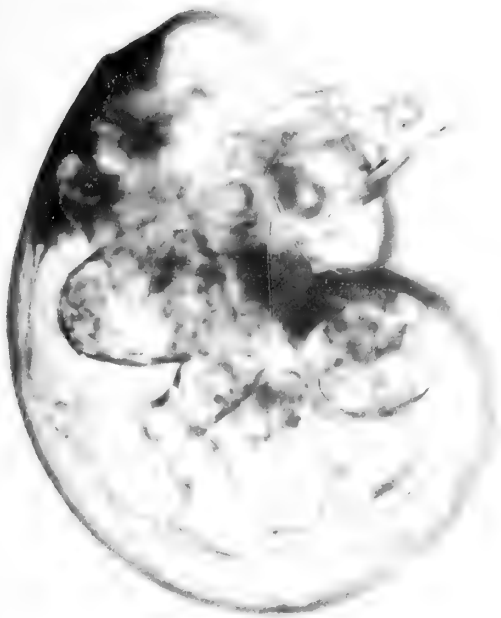


Figure 33: Veliger of *Archidoris montereyensis*

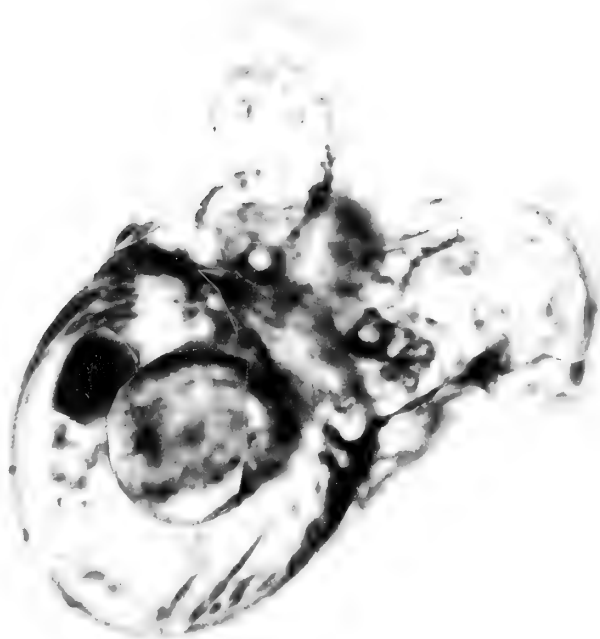


Figure 34: Veliger of *Armina californica*

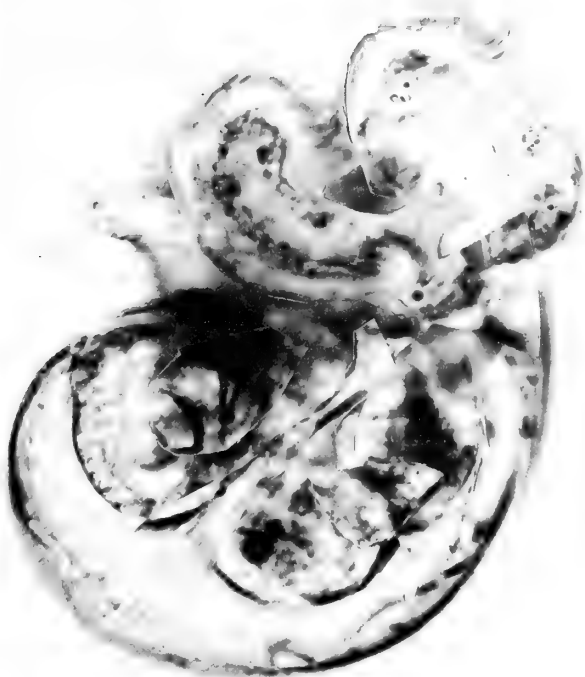


Figure 35: Veliger of *Armina californica*

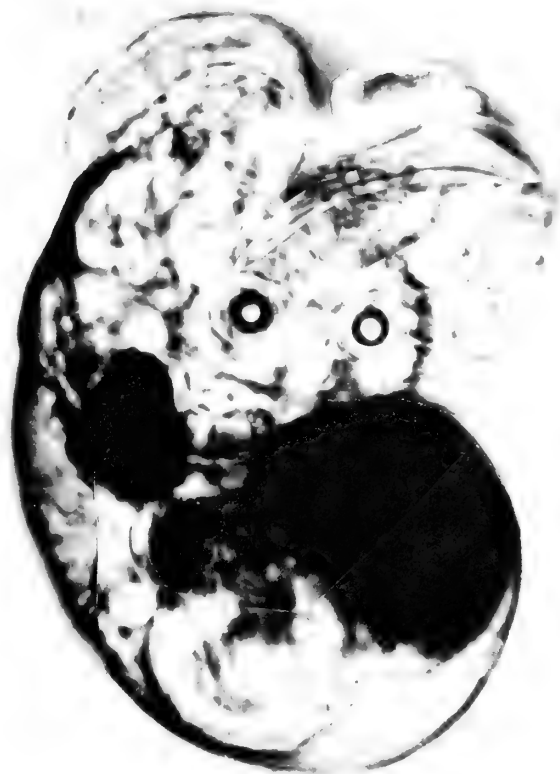


Figure 36: Veliger of *Chelidonura phocae*



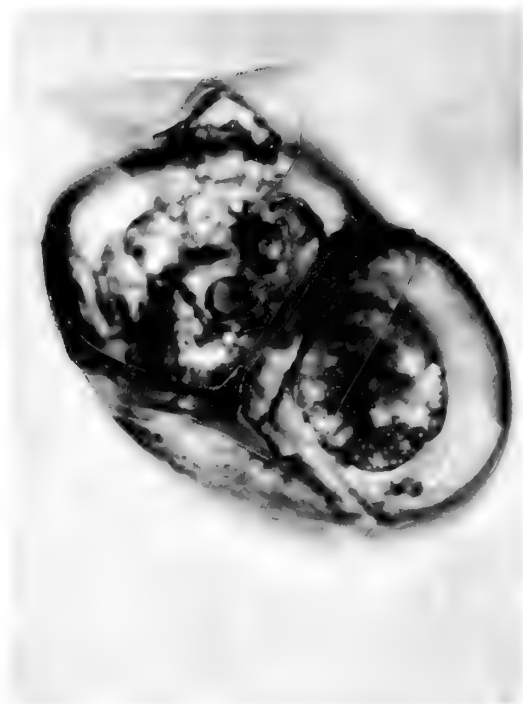


Figure 37: Veliger of *Coryphella fusca*

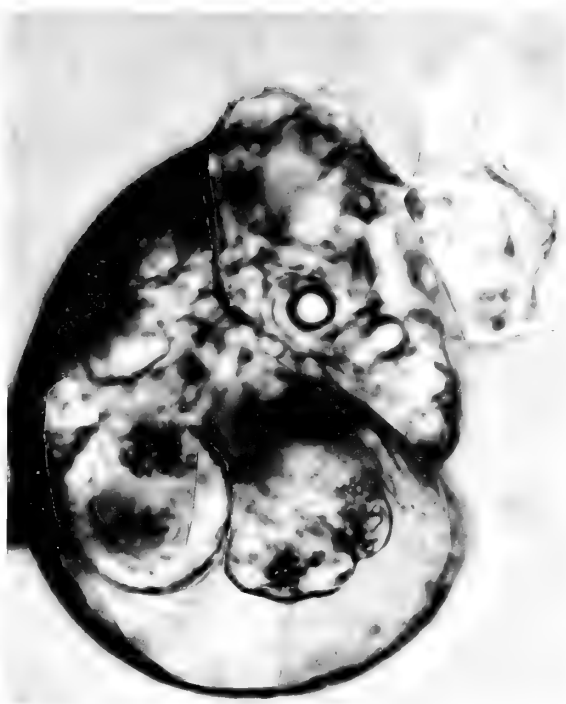


Figure 38: Veliger of *Coryphella rufibranchialis*



Figure 39: Veliger of *Cumanotus beaumonti*

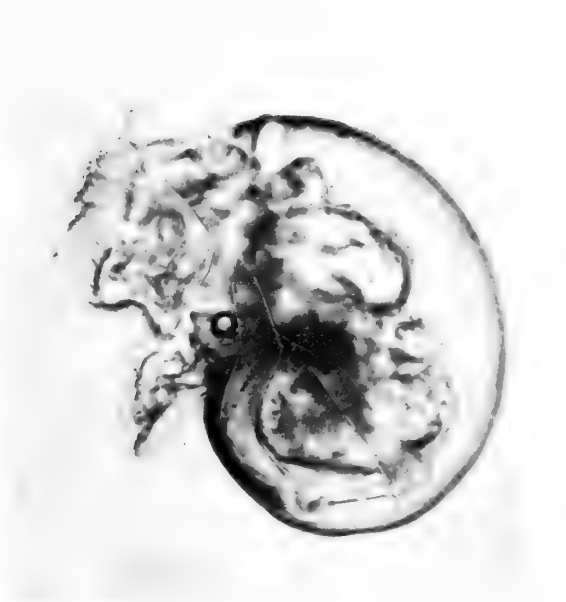


Figure 40: Veliger of *Diaulula sandiegensis*



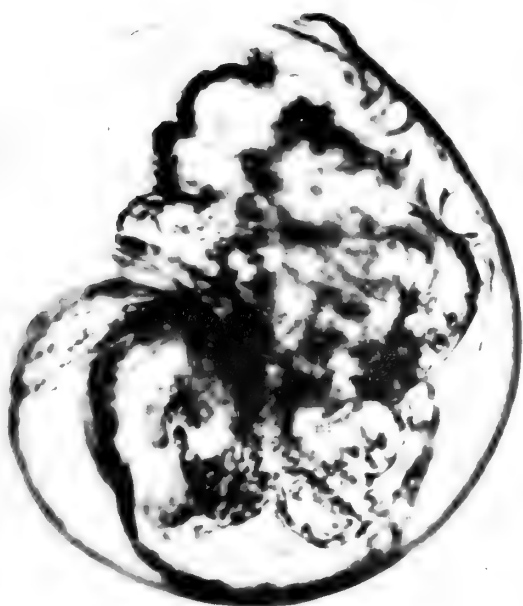


Figure 41: Veliger of *Dirona albolineata*



Figure 42: Veliger of *Gastropteron pacificum*



Figure 43: Veliger of *Haminoea virescens*

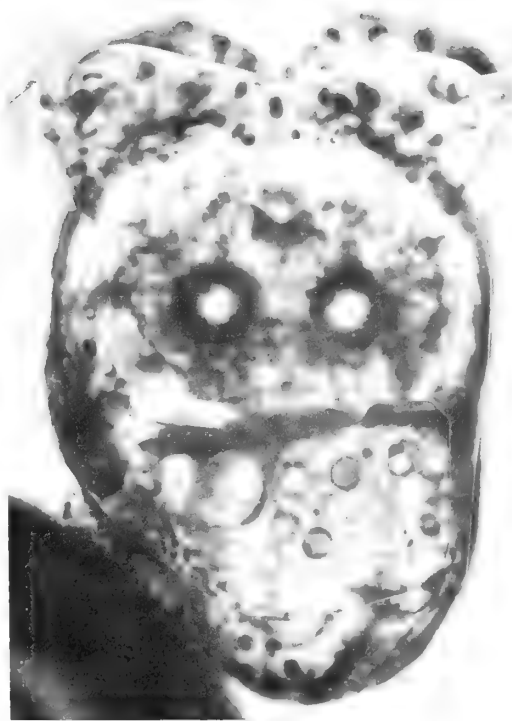


Figure 44: Veliger of *Olea hansineensis*





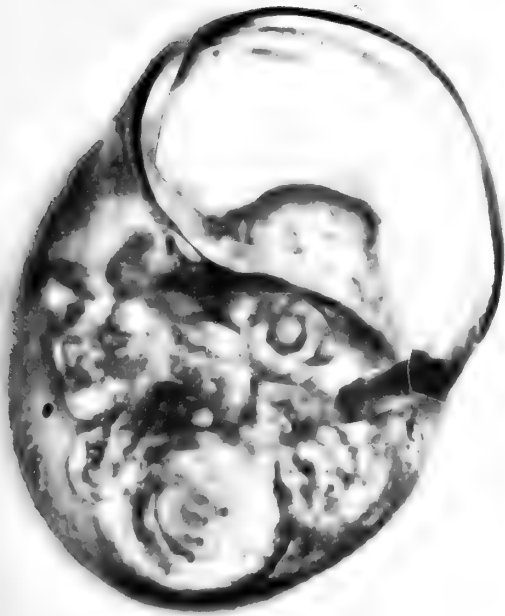


Figure 45: Veliger of *Onchidoris bilamellata*



Figure 46: Veliger of *Onchidoris muricata*



Figure 47: Veliger of *Rostanga pulchra*



Figure 48: Veliger of *Tritonia exsulans*





Figure 49: Veliger of *Dendronotus iris*

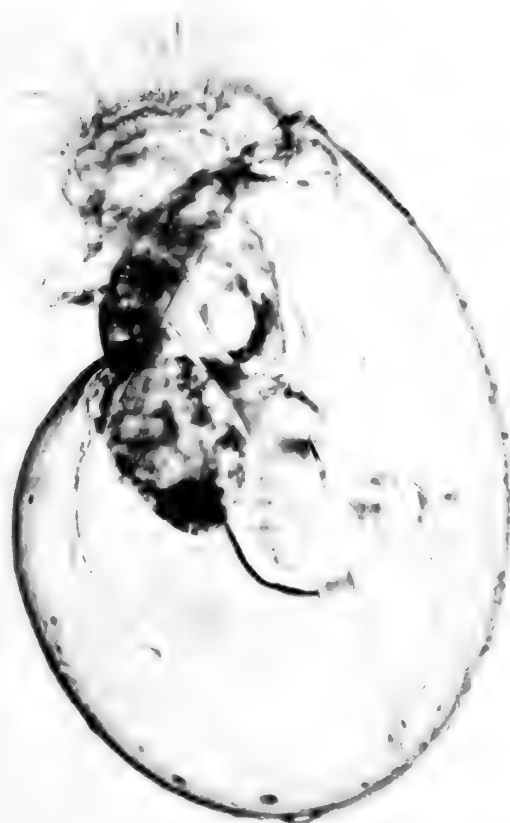


Figure 50: Veliger of *Dendronotus iris*

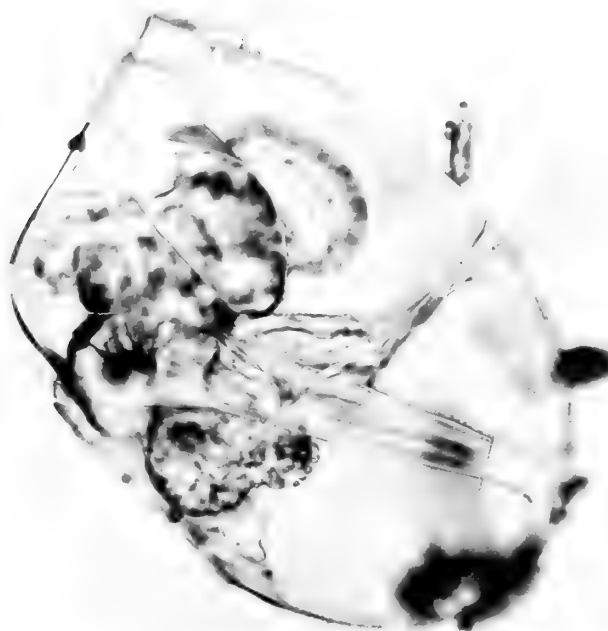


Figure 51: Veliger of *Eubranthus olivaceus*



neys, which were red before hatching; *Haminoea virescens* veligers had red kidneys. THORSON (1946) describing the veliger of the cephalaspid *Philine* mentioned that it had a black kidney. None of the veligers of other groups showed this pigmentation, but the sacoglossans *Limapontia* (THORSON, 1946) and *Stiliger* (RASMUSSEN, 1951) also

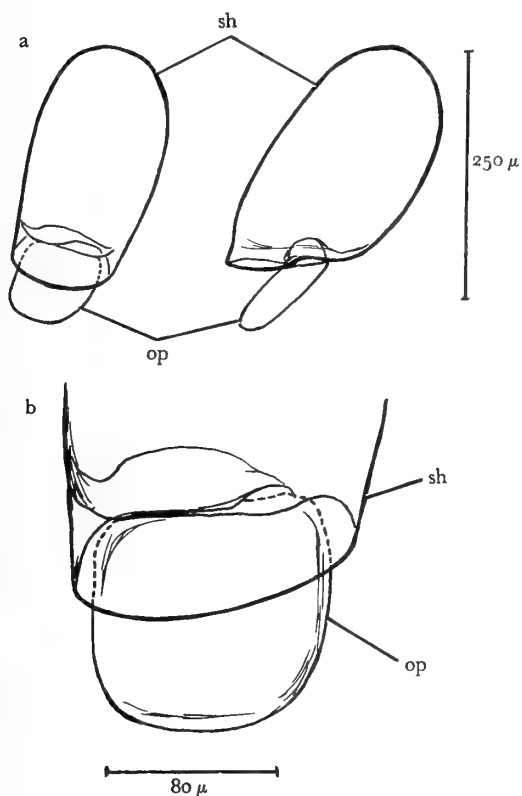


Figure 26 a

Two Empty Veliger Shells of *Cratena albocrusta*,  
with Operculum attached

Figure 26 b

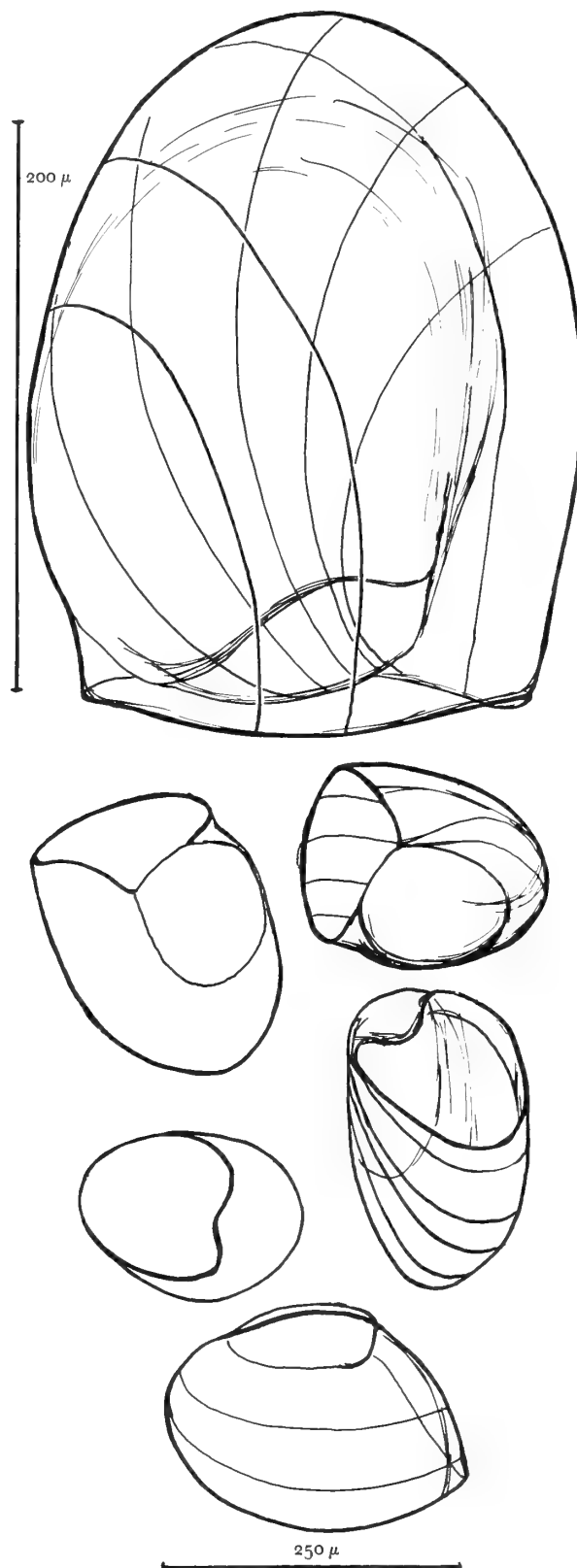
The Aperture End of a Veliger Shell of *Cratena albocrusta*  
with Operculum attached

op - operculum                      sh - shell

have darkly pigmented kidneys. It is possible that this is only a feature of the more primitive opisthobranchs, although it must be noted that not all of these possess it, for instance *Olea hansineensis* (Plate 36, Figure 44), also *Acera* and *Retusa* (THORSON, 1946).

Figure 27

Six Empty Veliger Shells of *Dendronotus ?frondosus*  
(possibly *Dendronotus rufus*)



All veligers observed had a bilobed velum (Text figures 28, 29: [vl]), which in some species—*Aglaia diomedea* (Plate 33, Figure 30), *Chelidonura phocae* (Plate 34, Fig. 36), *Austrodoris odhneri* (Plate 33, Figures 31, 32) — had

a very well marked sub-velar ridge (Text figure 28 [svr]). In others e. g. *Rostanga pulchra* (Plate 37, Figure 47) the lobes were particularly large — in *Rostanga pulchra* the large size and very rounded outline of the velar lobes made the veliger very distinctive. Animals of each species held the velum in a characteristic way — thus in some e. g. *Tritonia exsulans* (Plate 37, Figure 48), and *Acanthodoris hudsoni* (Plate 32, Figure 28), the velar lobes were wide-spread, so that their leading edges presented an almost straight line, while in most others e. g. *Archidoris montereyensis* (Plate 34, Figure 33), *Onchidoris bilamellata* (Plate 37, Figure 45) and *O. muricata* (Plate 37, Figure 46), the lobes were held at a much narrower angle. The length of velar cilia (Text figures 28, 29: [vc]) also varied from species to species.

The shell attachment of the columellar muscle (Text figures 28, 29: [cm]) was in a uniform position for each species — on the left side in all Type 1 veligers, except *Armina californica* (Plate 34, Figures 34, 35), in which it was on the right. In Type 2 veligers the position of attachment was specifically characteristic as were the fine muscular strands [mm] running in the mantle [ma] (*Dendronotus iris* (Plate 38, Figures 49, 50), *Cratena albocrusta* (Text figure 29)). Muscular strands may also be distinguished in Type 1 veligers e. g. *Melibe leonina* (Text figure 28: [mm]), but are harder to discern due to the closeness of the mantle [ma] to the organ systems of the body.

The foot (Text figures 28, 29 [f]) was rather similar amongst the various species of veligers, though some had particularly long cilia at the tip or sides of the foot e. g. *Melibe leonina* (Text figure 28: [sc]), *Dendronotus iris*. At least a third of the species examined had such special, probably sensory, cilia characteristically placed. In *Gastroperteron pacificum* (Plate 36, Figure 42) the foot was very long and projected past the edge of the operculum [op] curling over it. In *Cratena albocrusta* (Text figure 29) the foot is relatively much longer than in other Type 2 veligers. The size of the operculum varied, in some species almost filling the shell aperture on withdrawal, in others e. g. *Archidoris montereyensis* (Plate 34, Figure 33), *Tritonia exsulans* (Plate 37, Figure 48), being smaller. The veliger of *Cratena albocrusta* was also the only one to possess eyes (Text figure 29: [e]). These were reddish in colour and were present even before hatching. As THORSON (1946) has indicated, the presence of eyes in opisthobranch veligers is very unusual.

The plan of the digestive system was very similar in all Type 1 veligers e. g. *Melibe leonina* (Text figure 28: [dg, in, m, oe, st]) and is as described by THOMPSON (1959). Type 2 veligers also had a rather uniform gut plan, e. g. *Cratena albocrusta* (Text figure 29: [dg, in, m, oe, st]), *Dend-*

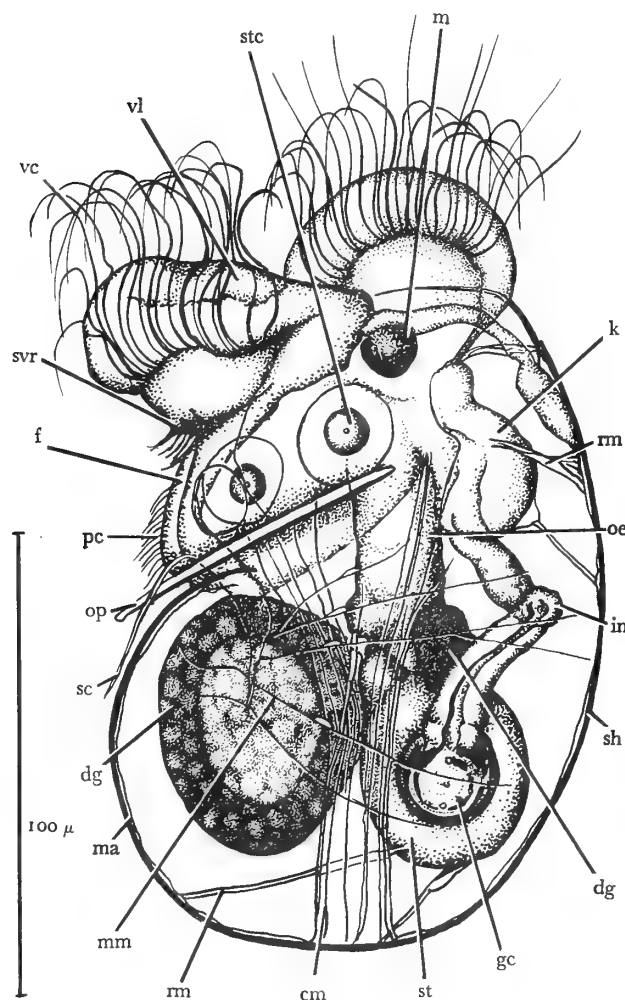


Figure 28

A Typical Veliger of Type 1 — that of *Melibe leonina*

- |                           |                       |
|---------------------------|-----------------------|
| cm — columellar muscle    | op — operculum        |
| dg — digestive gland      | pc — pedal cilia      |
| f — foot                  | rm — retractor muscle |
| gc — gut contents         | sc — sensory cilium   |
| in — intestine            | sh — shell            |
| k — kidney                | st — stomach          |
| m — mouth                 | stc — statocyst       |
| ma — mantle               | svr — subvelar ridge  |
| mm — mantle muscle fibres | vc — velar cilia      |
| oe — oesophagus           | vl — velum            |

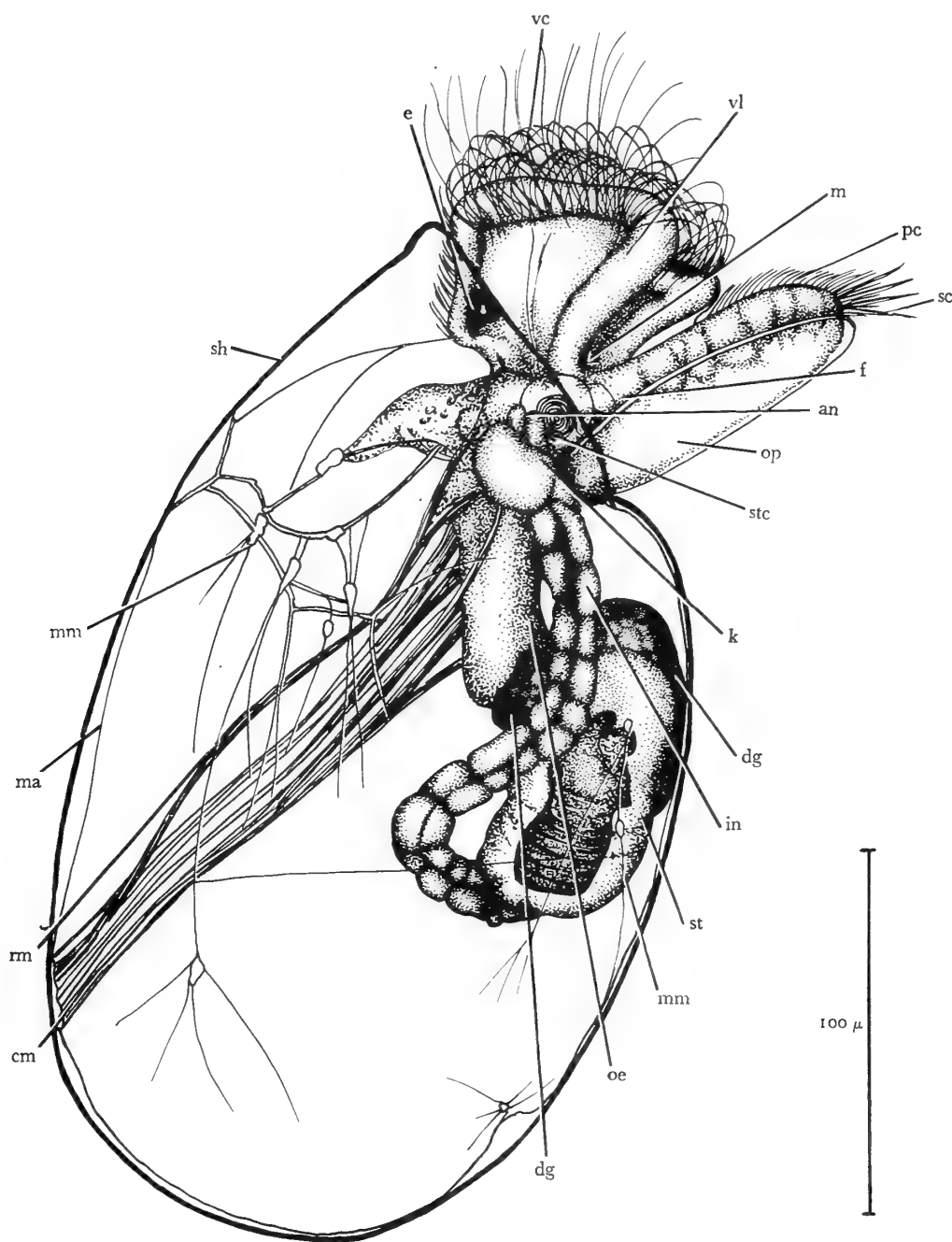


Figure 29

A Veliger of Type 2, - that of *Cratena albocrusta*

an - anus	in - intestine	oe - oesophagus	sh - shell
cm - columellar muscle	k - kidney	op - operculum	st - stomach
dg - digestive gland	m - mouth	pc - pedal cilia	stc - statocyst
e - eye	ma - mantle	rm - retractor muscle	vc - velar cilia
f - foot	mm - mantle muscle fibres	sc - sensory cilium	vl - velum

*ronotus iris* (Plate 38, Figures 49, 50). In a few species the digestive gland was of a very distinctive and characteristic colour, at least in very young veligers – thus in *Haminoea virescens* (Plate 36, Figure 43) it was bright yellow, in *Rostanga pulchra* (Plate 37, Figure 47) pinkish-red.

The behaviour of the veligers was of some help in broad separation of species, but further experimentation on this aspect would be beneficial. Some general indications have been noted however.

Before hatching veligers varied in activity, some, such as *Melibe leonina*, swimming about vigorously within the capsules, others e. g. *Haminoea virescens* spinning at a great rate, yet others e. g. *Dirona aurantia*, *Archidoris montereyensis* being relatively inert. Often the rather inactive veligers belonged to species with crowded egg masses and also tended to take longer to escape from the capsules. Most species with Type A or C egg masses had fairly active veligers. Hatching occurs by rupture of the capsule wall. This is probably achieved largely by the movements of veligers within. After rupture and escape of the veligers the capsule wall collapses. The veligers

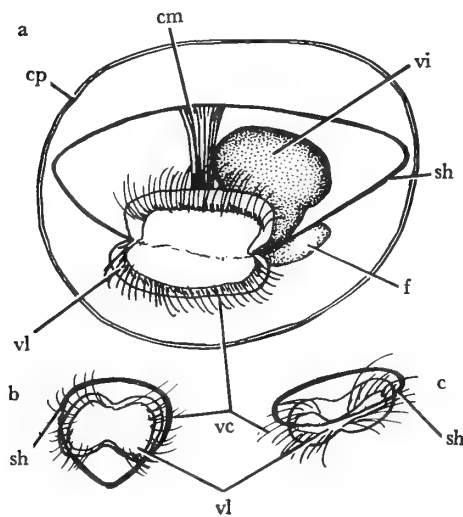


Figure 30a

Left Lateral View of an Early Type 2 Veliger before Hatching

Figure 30b

Ventral View of an Early Type 2 Veliger

Figure 30c

Anterior View of an Early Type 2 Veliger

- |                        |                  |
|------------------------|------------------|
| f – foot               | sh – shell       |
| cm – columellar muscle | vc – velar cilia |
| cp – capsule           | vi – viscera     |
|                        | vl – velum       |

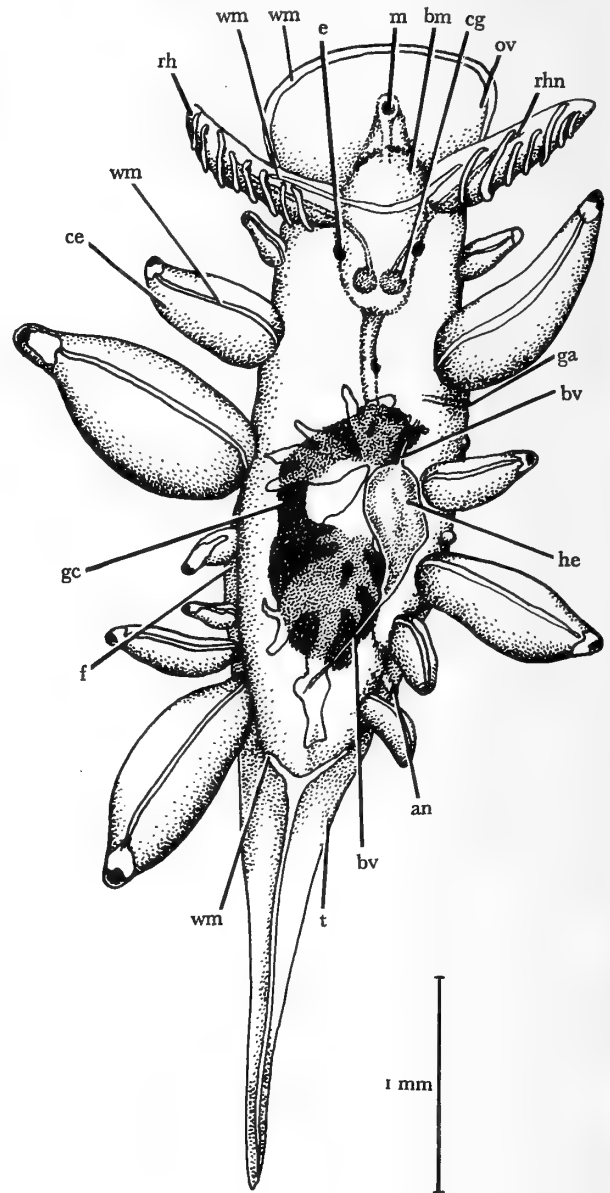


Figure 31

Dorsal View of Young *Dirona albolineata* at Post-Veliger, Pre-Adult Stage

- |                        |                        |
|------------------------|------------------------|
| an – anus              | gc – gut contents      |
| bm – buccal mass       | he – heart             |
| bv – blood vessel      | m – mouth              |
| ce – cerata            | ov – oral veil         |
| cg – cerebral ganglion | rh – rhinophore        |
| e – eye                | rhn – rhinophore nerve |
| f – foot               | t – tail               |
| ga – genital aperture  | wm – white marking     |



Table 9  
Species with Veligers of Type 1  
Shell Measurements in  $\mu$

	Observations	Length		Width		Depth		Ratios of Length : Width : Depth
		Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	
ATYIDAE								
<i>Haminoea virescens</i> :	30	139.5	6.0	88.2	5.7	99.7	6.8	1.58 : 1 : 1.13
GASTROPTERIDAE								
<i>Gastropteron pacificum</i> :	10	158.2	3.6	105.8	3.8	102.6	4.4	1.50 : 1 : 0.97
AGLAJIDAE								
<i>Aglaja diomedea</i> :	30	180.0	8.9	116.5	7.2	122.9	7.6	1.55 : 1 : 1.06
<i>Chelidonura phocae</i> :	10	144.7	5.0	97.7	3.1	100.4	2.8	1.48 : 1 : 1.03
OLEIDAE								
<i>Olea hansineensis</i> :	10	110.7	3.8	75.1	3.1	75.6	3.6	1.47 : 1 : 1.01
TRITONIIDAE								
<i>Tritonia exsulans</i> :	20	146.3	8.0	98.3	4.8	107.5	10.8	1.49 : 1 : 1.09
POLY CERIDAE								
<i>Triopha carpenteri</i> :	10	134.5	4.7	89.1	2.8	97.7	4.7	1.51 : 1 : 1.10
<i>Acanthodoris brunnea</i> :	20	119.1	5.1	80.5	1.7	87.2	3.2	1.48 : 1 : 1.08
<i>Acanthodoris nanaimoensis</i> :	10	133.4	4.4	83.7	3.8	89.6	3.8	1.59 : 1 : 1.07
<i>Onchidoris bilamellata</i> :	10	146.9	8.7	95.0	5.2	108.0	5.1	1.55 : 1 : 1.14
<i>Onchidoris muricata</i> :	10	185.8	6.8	131.8	9.2	139.3	5.0	1.41 : 1 : 1.06
DORIDIDAE								
<i>Rostanga pulchra</i> :	10	161.5	4.0	113.9	3.1	110.2	2.8	1.42 : 1 : 0.97
<i>Archidoris montereyensis</i> :	10	155.0	6.3	103.1	3.1	113.9	3.1	1.50 : 1 : 1.11
<i>Austrodoris odhneri</i> :	10	188.5	6.5	131.8	6.4	144.7	4.3	1.43 : 1 : 1.10
<i>Diaulula sandiegensis</i> :	10	153.4	5.8	95.6	3.6	112.3	4.3	1.61 : 1 : 1.18
ARMINIDAE								
<i>Armina californica</i> :	10	159.8	4.6	104.2	3.6	113.4	4.4	1.53 : 1 : 1.09
DIRONIDAE								
<i>Dirona albolineata</i> :	20	112.6	3.2	85.3	2.2	86.4	3.0	1.32 : 1 : 1.01
<i>Dirona aurantia</i> :	10	138.8	5.7	94.0	7.3	97.2	6.7	1.48 : 1 : 1.03
TETHYIDAE								
<i>Melibe leonina</i> :	20	152.0	8.3	108.5	6.0	115.0	7.5	1.40 : 1 : 1.06
FLABELLINIDAE								
<i>Coryphella fusca</i> :	20	133.4	4.3	85.6	4.0	98.8	8.6	1.56 : 1 : 1.15
<i>Coryphella ?rufibranchialis</i> :	20	116.6	4.4	80.5	2.4	87.2	4.7	1.45 : 1 : 1.08
<i>Cumanotus beaumonti</i> :	20	119.1	6.4	88.0	2.5	87.2	4.4	1.35 : 1 : 0.99
AEOLIDIIDAE								
<i>Aeolidia papillosa</i> :	10	137.7	6.9	90.2	4.4	101.5	7.6	1.53 : 1 : 1.13
<i>Hermisenda crassicornis</i> :	20	116.1	5.1	84.8	4.3	88.3	5.3	1.37 : 1 : 1.04

may swim for a while within the egg mass before freeing themselves from it – particularly in species with egg masses of Type C e. g. *Aglaja diomedea* (Plate 33, Figure 30).

After hatching the sorts of activity shown by veligers were not uniform. Thus although the response to light of all species tested (*Acanthodoris nanaimoensis*, *Archidoris montereyensis*, *Haminoea virescens*, *Hermisenda crassicornis*, *Onchidoris bilamellata*, *Tritonia exsulans*)

was positive – veligers collecting in the light except where it was of extreme brightness, and being more active in the light – some showed a much more marked tendency under normal conditions, to swim up to the surface and get stuck on the surface film. Thus for instance in *Armina californica* (Plate 34, Figures 34, 35), *Melibe leonina* (Text figure 28) and *Hermisenda crassicornis* populations, the surface film would be crowded with stranded veligers within 48 hours of hatching, whereas in *Hami-*

*noea virescens* (Plate 36, Figure 43), *Gastropteron pacificum* (Plate 36, Figure 42) and others, very few became stuck over a long period of time. (Cetyl alcohol flakes, added to reduce surface tension, effectively reduced mortality from this cause.) The amount and type of activity within the dishes containing veligers (under very similar conditions) was also variable – thus in populations of e. g. *Diaulula sandiegensis* (Plate 35, Figure 40), *Onchidoris bilamellata* (Plate 37, Figure 45), *Coryphella fusca* (Plate 35, Figure 37) the veligers were lively and swam about continuously, or in e. g. *Haminoea virescens* moved about the bottom of the dish in large numbers, whereas in e. g. *Cumanotus beaumonti* (Plate 35, Figure 39), the veligers gathered together in a group and swam vigorously only when shaken up. In most species (those specifically tested included *Acanthodoris nanaimoensis*, *Archidoris montereyensis*, *Haminoea virescens*, *Hermisenda crassicornis*, *Tritonia exsulans*) there seemed to be a positive thigmotactic response and the veligers appeared to be gregarious.

The movements of the veligers were largely similar to the activities of CARTER's (1926) four species of nudi-

branch veligers. Thus: the velar cilia beat outwards and in forward swimming (velum first) the effective stroke was backwards. Also, the veligers showed the intermittent halts in activity, not due to fatigue, that CARTER mentioned. In most of the species considered here, the velar cilia gathered in a bunch (as in all the veligers in Plate 35) for a short interval before continuing to beat. In a few species the halt position was different: thus in *Tritonia exsulans* the cilia flattened down and out around the edges of the velum – the cilia reached this position a few at a time and some few remained pointing forwards during the time of rest. Those fanned out were not quite inactive, since they would frequently hump up slightly and an occasional one would straighten upwards. Commonly in various species a few velar cilia would act differently from the rest – e. g. in *Hermisenda crassicornis* a few on either side of and closest to the mouth, would remain curled over towards it for long periods. Besides recurring at fairly regular intervals, the halt position in all species, as mentioned by CARTER, was also initiated by a sudden contact with, for instance, another veliger (which would help to encourage clumping of

Table 10  
Analysis of Variance in Shell Samples using f Tests

Species with Veligers of Type 1	Observations	Number of samples	Length Width Depth (significant difference at 0.01 and 0.05 level)		
ATYIDAE					
<i>Haminoea virescens</i> :	30	3	—	—	—
AGLAIIDAE					
<i>Aglaja diomedea</i> :	30	3	0.05	0.05	0.05
TRITONIIDAE					
<i>Tritonia exsulans</i> :	20	2	0.01	—	0.05
POLYCERIDAE					
<i>Acanthodoris brunnea</i> :	20	2	—	—	—
DIRONIDAE					
<i>Dirona albolineata</i> :	20	2	—	—	—
TETHYIDAE					
<i>Melibe leonina</i> :	20	2	—	—	—
FLABELLINIDAE					
<i>Coryphella fusca</i> :	20	2	0.01	—	0.05
<i>Coryphella ?rufibranchialis</i> :	20	2	—	—	—
<i>Cumanotus beaumonti</i> :	20	2	0.01	—	0.05
AEOLIDIIDAE					
<i>Hermisenda crassicornis</i> :	20	2	0.05	—	0.05
Species with Veligers of Type 2					
TERGIPEDIDAE					
<i>Cratena albocrusta</i> :	20	2	—	—	—

Table 11  
Species with Veligers of Type 2

Shell Measurements in $\mu$								
	Observations	Length		Width		Depth		Ratios of Length : Width : Depth
		Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	
DENDRONOTIDAE								
<i>Dendronotus iris</i> :	10	202.5	3.8	158.2	2.6	268.4	4.4	1.28 : 1 : 1.70
FLABELLINIDAE								
<i>Eubranchius olivaceus</i> :	10	177.1	6.1	177.7	5.4	244.6	7.2	1.00 : 1 : 1.38
TERGIPEDIDAE								
<i>Catriona aurantia</i> :	10	177.1	10.7	173.3	9.3	230.0	6.0	1.02 : 1 : 1.33
<i>Cratena albocrusta</i> :	20	172.8	11.5	165.8	14.5	270.5	12.7	1.04 : 1 : 1.63

veligers where many are together in a confined space) or the surface film. A stronger tactile stimulus or one of a chemical nature, caused semi- or complete withdrawal. Whether in halt position or withdrawn, the veliger will sink slowly until velar ciliary action begins again.

Straight forward (or occasionally backward) swimming was common. Speed varied according to the number and vigour of the cilia in action and the extent of protrusion of the velum. The velar cilia appear to work in groups which may be separated in regions or may intermingle with each other. Thus in *Armina californica* three groups were apparent – these were intermingled: one group was fanned out over the edges of the velum in a rest position as in *Tritonia exsulans*, another group was beating gently with less amplitude than the third group, which was beating very vigorously, completely straightening out during the effective part of the stroke.

A circling movement was very frequent: the veligers turned swiftly in a right-handed circle, achieved by semi-withdrawal of the right velar lobe and markedly stronger velar ciliary action of the left lobe. This was observed in most species e. g. *Acanthodoris nanaimoensis*, *Aeolidia papillosa*, *Coryphella fusca*, *Hermisenda crassicornis*, *Melibe leonina*, *Tritonia exsulans*. In this circling, a few velar cilia of the outer edge of the right velar lobe are held out stiffly and do not beat. Another common action was spinning on the horizontal median axis of the body – either forwards (*Haminocoe virescens*) or backwards (*Hermisenda crassicornis*, *Melibe leonina*).

Where veligers were moving over the bottom of the dish, they usually moved forwards, with the velum very close to the substratum. Small objects stirred up by the

resultant current may be swept into the mouth by the continuous current sent in that direction by the pedal and oral cilia. These small cilia beat all the time and do not have periods of inactivity related to those of the velar cilia. In *Tritonia exsulans* it was noted that the velar lobes may be held at such an angle that the velar cilia may partially obscure the mouth. This may be a device used to keep large particles out. In most species small particles were being swirled round by ciliary action in stomach and digestive gland, as described by THOMPSON, 1959. In some cases e. g. *Diaulula sandiegensis*, which took diatoms, these were identifiable. Although feeding was apparently taking place, no supplementary food was added and no obvious growth of veligers occurred, at least as far as their shells were concerned.

In some species mortality was high, even within the egg mass e. g. *Rostanga pulchra*, *Archidoris montereyensis*; however, both these species lay eggs in strong water currents in the field. This reduces infestation by copepods and ciliates, which were, at least in part, responsible for reducing chances of viability of the young stages within the egg masses. Use of antibiotics, as described by VLASBLOM (1961) was not a very effective deterrent to such infestation. Veligers of most species, once hatched, were frequently transferred if dishes became dirty, and survived for at least a fortnight. Some populations e. g. *Cumanotus beaumonti*, *Aglaja diomedea*, *Gastropteron pacificum* survived for over a month. In no case was metamorphosis observed to occur, even where the adult foodstuff (e. g. *Ophlitaspongia* with *Rostanga pulchra* veligers) or adults or both were present.

## DISCUSSION

DEHNEL (1955) noted that the morphology of egg masses may be an important component in the discussion and description of many invertebrate species and that this alone may identify the adult. This is no less true of the morphology of the larval stages. In opisthobranchs identification is frequently difficult and additional descriptive information concerning the young stages is useful. Although there is similarity between the egg masses of many opisthobranchs and also between their veligers, it is often possible to identify adults from these stages. Besides being of taxonomic use, this is also helpful in ecological and other studies of both benthic and planktonic communities, of which opisthobranch young stages may form a significant part.

The North-East Pacific species considered in this survey could each be readily distinguished from egg masses or veligers. Later larval or postlarval stages are likely to be even more distinctive, although difficulties in rearing them precludes description here of their morphology. Occasionally young opisthobranchs at post-veliger and pre-adult stage occurred in the aquarium e. g. *Dirona albolineata* (Text figure 31) and these could be identified. Both egg masses and veligers may be separated only broadly unless some detailed examination is made. Differences in egg masses perceptible to the unaided trained eye are difficult to analyse even with the aid of a microscope and, as with adult opisthobranchs, colour slides are invaluable. However, the type of information included in Tables 1 to 8 makes specific identification possible, and study of greater numbers of egg masses would define limits of variability and averages more precisely. It should also be possible to calculate the correlation, in various species, between size of the parent and the size and numbers of the components of its egg mass. More information on seasonality would be advantageous, although (as mentioned under *Rostanga pulchra*) it is very likely that this varies with regional conditions, in timing and extent.

Veligers may be identified to species, using a variety of characteristics, emphasis in this paper being made on shells. In these sculpture is not very variable within species but may be obscured with deterioration of the shell after it is shed (patterns being obliterated by abrasion or algal growth); shape also is fairly constant although some aberrant forms occur, particularly in unhealthy egg masses – these in many cases would probably not survive under natural conditions, having a high mortality even in the laboratory; size measurements require a more extensive discussion. Sample variance may be due to one or more

of the following causes: methods of sampling; methods of measuring; variation in samples. The sampling would give better results if larger numbers were used and the method did not take into account possible growth and age difference between the populations. The amount of shell growth occurring appeared negligible under laboratory conditions as found by THORSON (1946). The absence of obvious growth also agrees with THOMPSON's view (1959), that large amounts of growth are impossible due to retraction of the mantle at an early stage, from the edges of the shell. However, RASMUSSEN (1944, 1951) found larger veligers in the plankton than those of the same species raised in the laboratory. This indicates that at least some opisthobranch veligers spend feeding time in the plankton, which is effective as reflected in growth, although it may be short as THORSON (1946) considers.

If small amounts of shell growth occurred, depth measurements would probably be affected more than length and both more than width, since new material is added to the aperture edge, the greatest amount at the anterior lip (Text figure 21). This would cause the shell to project mainly downwards and the effect would be reflected mainly in the depth measurement, except in the case of a shell with a widely flaring aperture (Text figure 22). Text figure 22 also illustrates how measurements are affected by orientation, which is also a source of potential error. Table 10 (f tests) shows that variance was greatest in depth, least in width and this may incorporate the effects of both slight growth and non-uniform orientation. (However, since orientation was as uniform as possible averaging probably cancelled out slight differences due to this cause). A symmetrical shell where the inner, more posterior part of the whorl is as wide and long as the aperture is the easiest type to measure accurately e.g. *Coryphella rufibranchialis* (Text figure 24 [4]). Those with a flared aperture such as that of *Haminoea virescens* (Text figure 24 [12]) or *Gastropteron pacificum* (Text figure 24 [19]) are more difficult to orient correctly. The effect of curvature of the shell and the relative width of the aperture on measurement with or without growth is demonstrated by Text figures 21 and 22. It is also apparent that the tangent chosen for measurement particularly of length, may cause a marked difference in the result, especially in a determination of whether or not growth has occurred. In measuring Type 2 veliger shells the angle of inflation (Text figure 23) caused the measure of the longest axis (substituted for depth) to be the most variable of all measurements in that uniformity between measuring for different species was not possible. It is considered that the differences in the f tests of some species and some of the larger stand-

ard deviations (Table 9) e. g. *Tritonia*, are largely due to the shape and orientation of shells. The extent of variance between populations of veligers of different parental origin could be ascertained by wide statistical analysis beyond the scope of this paper.

It seems likely that when more species have been fully described, field identification of veligers from the plankton will be possible but only by the use of comprehensive comparative data in tables and keys, although separate descriptions such as those of CHUKHCHIN (1960), HAMATANI (1960 a, b, 1961 a, b), PELSENEER (1911), RASMUSSEN (1944, 1951), THORSON (1946) and others are also of value. With this aim in mind, future descriptions could with advantage include details such as veliger type (after THOMPSON, 1961); average dimensions (with standard deviations) of shells; pattern and distribution of sculpture; shape, presence or absence of eyes, pigmentation of kidney or other parts of the body, specialized sensory cilia—number and position; shape, size and orientation of the velar lobes; length of velar cilia; size, activity and appearance of the statocysts and size of the statocyst chamber; relative lengths of foot and operculum; relative size of operculum and shell aperture; other characteristics which may be peculiar to particular species. Behavioural characteristics both before, immediately after and well after hatching may also help in identification.

The numbers of opisthobranch larvae occurring in plankton samples are relatively low (THORSON, 1946) and they are poorly equipped for planktonic life, as compared with prosobranch veligers, having small velar lobes and sometimes cumbersome shells. On observing the behaviour of opisthobranch veligers, which are passive intermittently, sinking when the velar cilia are not beating, and spend much time moving closely over the substratum, it seems likely that they may remain near the bottom for at least part of their lives before metamorphosis.

### ACKNOWLEDGMENTS

Thanks are due to Dr. R. L. Fernald, Director of the Friday Harbor Laboratories, for the use of facilities and to the National Science Foundation for financial support. The author is grateful to others who gave valuable assistance. These include Dr. K. M. White and Professors E. and E. Marcus who provided or confirmed the identity of many species considered; Dr. A. J. Kohn who made available some data on *Olea hansineensis* and critically read the typescript; Miss E. Marks who helped organize information for the section on veliger shells.

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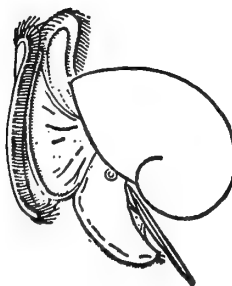
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# A New Species of *Morum* from Brazil, with Remarks on Related Species

(Gastropoda : Tonnacea)

BY

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(Plate 39; 1 Text figure)

MR. HENRY R. MATTHEWS of Fortaleza, Brazil recently submitted to us for examination a small collection of shelled mollusks taken from the digestive tracts of bottom-feeding fishes that were caught off the Brazilian coast of Ceará. Among this material are specimens of a new species of *Morum*, and I take extreme pleasure in naming this discovery in honor of Mr. Matthews.

*Morum* RÖDING, 1798

Type species: *Morum purpureum* RÖDING, 1798  
[=*Strombus oniscus* LINNAEUS, 1758], by monotypy; Recent, southern Florida to Brazil

According to WOODRING (1959, p. 202), representatives of *Morum* (s. s.), which are strongly nodose forms, are not known from the American Caribbean region before Pliocene time. A nominal species, *Morum floridana* TUCKER & WILSON (1933, p. 71, pl. 10, figs. 3-5), was described from the Plio-Pleistocene of Florida. In the Recent fauna, only two species are recognized. These are *M. oniscus* (LINNAEUS, 1758) and *M. tuberosum* (REEVE, 1842) which occur, respectively, in the tropical, western Atlantic and eastern Pacific Oceans. *Morum oniscus* also occurs in the Moín formation of late Pliocene age in eastern Costa Rica, and *M. tuberosum* is known from late Pleistocene deposits in western Mexico and the Galapagos Islands. The more numerous cancellate species, which were recently placed in the subgenus *Cancellomorum*, have been referred erroneously by students to either "*Oniscidia* SWAINSON" or "*Onimusiro* KIRA, M.S."

(see WOODRING, 1959). This distinctive group first appears in the Eocene of the American Caribbean and the European Mediterranean. The European elements, however, became extinct by the end of the Miocene epoch. By this time, the group had become essentially circumtropical in distribution; however, by the close of the Tertiary, their modern descendants survived only in the tropical waters of the western Pacific and western Atlantic Oceans.

The earliest known representatives of *Cancellomorum* in the New World are two taxa reported from middle Eocene deposits. One small specimen, measuring only 14 mm in length, was described as *Morum* (*Cancellomorum*) *scotlandica* (TRECHMANN, 1925, p. 491, pl. 24, figs. 18a, b) from the Scotland Beds of Barbados. A fragment of a small, unnamed specimen was recorded by WOODRING (1959, pp. 202, 203, pl. 25, figs. 11, 17) from the Gatuncillo formation of the Panama Canal Zone. Other New World species, some with European affinities, have been described from late Eocene to early Oligocene deposits in Mississippi, Panama, Colombia, and Peru.

In the American Miocene, species are reported from Florida, Panama, Dominican Republic, Carriacou Island (The Grenadines), and Brazil. Two closely related, if not conspecific species, have been described from Plio-Pleistocene of Florida.

(*Cancellomorum*) EMERSON & OLD,  
1963

Type species: *Morum grande* (A. ADAMS, 1855), by original designation; Recent, off southern Japan.

*Morum (Cancellomorum) matthewsi* EMERSON  
spec. nov.

Plate 39, Figures 2 to 4; Text figure 1

Shell is small, attaining a length of 28 mm, imperforate, solid, strong, low-spined, with 4 postnuclear whorls. Nucleus is large, papilliform, with 3 whorls. Body whorl is shouldered below the sutural depression, sculptured with weak, blade-like axial ridges which form small, longitudinally compressed plications at the intersection of the 6 spiral ridges. Interspaces between the plications are sculptured with fine axially arranged threads. Aperture is semi-crescentic in outline. Outer lip is reflected, thickened and possesses about 15 major to minor liraform "teeth" along the length of the inner margin. Inner lip is covered with a thick callus which is ornamented with numerous lirations, some of which terminate abaperturally as small pustules. Operculum was not seen.

The nucleus is white, and the postnuclear whorls have a base color of pinkish white that is stained with irregular patches of reddish brown, which occur most prominently as two spiral bands that terminate on the outer lip. The callus on the parietal wall is colored a deep-purplish red, except the lirations and pustules, which are whitish. The "teeth" on the outer lip are also white.

Measurements: Holotype, 25.1 mm in length, 15.5 mm in width; largest paratype, 28.3 mm by 18.3 mm; smallest paratype (outer lip immature), 20.4 mm by 12.3 mm.

Type locality: off Fortaleza, Ceará, Brazil, in 15 fathoms, July, 1965, March, 1966 (from the digestive tracts of the toadfish, *Amphichthys cryptocentrus*).

Type depository: Holotype, A. M. N. H. catalogue no. 129201, and 4 paratypes, no. 129202, American Museum of Natural History; one paratype, British Museum (Natural History); one paratype, Museum of Comparative Zoology, Harvard University; hypotype (Text figure 1) Stanford University Paleontology type collection; hypotype, collection of B. Tursch. The last two hypotypes listed are fresh beach specimens from Acaraú, Ceará, Brazil. All paratypes are from the type locality.

The new species differs from *Morum (Cancellomorum) dennisoni* (REEVE, 1842, p. 111, pl. 54, figs. 5, 6), a rare Caribbean species occurring in deep water (75 to 130 fathoms), by its much smaller size, more prominent nucleus, fewer tubercles, and, most noticeably, by the orna-

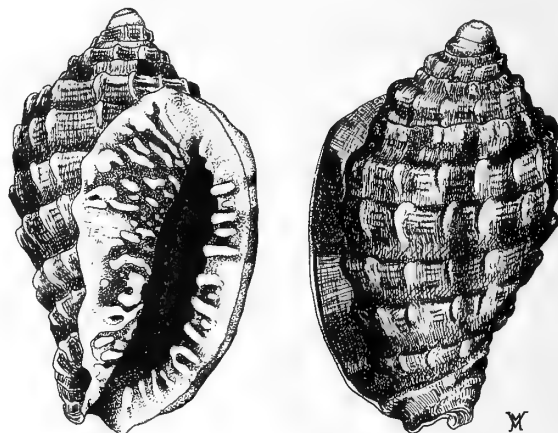


Figure 1

*Morum (Cancellomorum) matthewsi*, spec. nov.  
Hypotype from beach-drift at Acaraú, Ceará, Brazil.  
(Stanford Univ. Paleo. Type Coll.; ex B. Tursch); greatly enlarged  
(length of specimen - 27.5 mm).  
Drawing courtesy of Dr. J.-J. Van Mol.

mentation and color of the parietal callus. REEVE's taxon, of which a probable cotype, from the John Calvert Collection, is deposited in the American Museum (see Plate 39, Figure 1), attains a length of more than 53 mm and is easily distinguished by its pustulate parietal callus which has a base color of light reddish brown and whitish pustules. *Morum dennisoni* appears to have evolved from one of several known, slightly smaller Miocene species, possibly *M. (C.) chipolanum* "DALL" MAURY (1925, pl. 4, fig. 4, GARDNER, 1947, pl. 54, fig. 18; Chipola formation, Florida). *Morum matthewsi*, spec. nov., on the other

### Explanation of Plate 39

*Morum (Cancellomorum) dennisoni* (REEVE, 1842)

Figure 1: Probable cotype from the John Calvert collection, without locality data  
(A. M. N. H. no. 12818; ex Anthony D'Attilio collection); (x 1)

*Morum (Cancellomorum) matthewsi*, spec. nov.

Figures 2 - 4: Type specimens from off Fortaleza, Ceará, Brazil, in 15 fathoms, ex H. R. Matthews collection; (x 2)

Figure 2: Paratype (A. M. N. H. no. 129202 a); juvenile specimen.

Figure 3: Holotype (A. M. N. H. no. 129201); mature specimen.

Figure 4: Paratype (A. M. N. H. no. 129202 b); specimen with an immature outer lip and with the parietal callus not fully developed.





Figure 1 a



Figure 1 b



Figure 2 a



Figure 2 b



Figure 3 a



Figure 3 b



Figure 4 a



Figure 4 b

*Morum (Cancellomorum) dennisoni* (REEVE, 1842)

Figure 1: Probable cotype from the John Calvert collection, without locality data (A. M. N. H. no. 12818; ex Anthony D'Attilio collection); (x 1)

*Morum (Cancellomorum) matthewsi*, spec. nov.

Figures 2 - 4: Type specimens from off Fortaleza, Ceará, Brazil, in 15 fathoms, ex H. R. Matthews collection; (x 2)

Figure 2: Paratype (A. M. N. H. no. 129202 a); juvenile specimen.

Figure 3: Holotype (A. M. N. H. no. 129201); mature specimen.

Figure 4: Paratype (A. M. N. H. no. 129202 b); specimen with an immature outer lip and with the parietal callus not fully developed.



hand, may be more closely allied to small fossils that appear in the late Cenozoic of Florida. These nominal species, *M. (C.) obrienae* OLSSON & PETIT (1964, pl. 80, figs. 8, 8a, Caloosahatchee marl) and *M. (C.) macgintyi* [sic] SMITH (1937, pl. 6, fig. 12; "?Unit A", *fide* OLSSON & PETIT, 1964) were described from Plio-Pleistocene deposits. The type specimens of these taxa have shells that are more inflated and possess much more strongly cancellate ornamentation than the shells of the new species described herein.

Passing mention should be made of "*Oniscia Strombiformis* REEVE" (1842, pl. 253, fig. 1; 1843, p. 91), a small, high-spined species with a pustulate parietal callus that was based on a specimen from an unknown locality in the Hugh Cuming Collection. REEVE (1849, *Oniscia*, pl. 1, fig. 2) subsequently cited it from "Honduras; Dyson." TRYON (1885, p. 282) listed it from the "West Indies", although he stated that it was unknown to him. CLENCH & ABBOTT (1943, p. 5) suggested that Cuming may have obtained it in the Philippine Islands. Mr. Peter Dance kindly compared a paratype of *Morum matthewsi* spec. nov. with Dyson's specimen from "Honduras", which is in the British Museum (Natural History). He noted that in *M. strombiformis*, "Its apex is pointed and high; it lacks the purple coloration in the aperture and in the callus; its sculpture is quite different and it has fewer teeth on the inner lip." And he concluded, "The type is nothing like your shell." Thus the status of *M. strombiformis* remains unchanged.

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In addition to Mr. Matthews, I am greatly indebted to the following individuals for courtesies of various kinds: Dr. R. Tucker Abbott of the Academy of Natural Sciences of Philadelphia; Messrs. Norman Tebble and Peter Dance of the British Museum (Natural History); Mr. Thomas L. McGinty of Boynton Beach, Florida; Dr. Wendell P. Woodring of the U.S. Geological Survey; and Mr. William E. Old, Jr. of the American Museum of Natural History.

My colleague, Mr. Anthony D'Attilio, generously donated to the American Museum a historically important specimen of *Morum (Cancellomorum) dennisoni* from the Calvert Collection (figured in this paper). This fine specimen was obtained by him several years ago when the Calvert Collection was offered for sale in New York City.

Shortly after the present manuscript was completed, I learned from Drs. Jean-Jacques Van Mol and Bernard Tursch of the Université Libre de Bruxelles that they had already submitted a manuscript to *The Veliger* in which they had described this interesting new species. Upon

learning of my manuscript, they generously withdrew their description of this taxon, and they have kindly permitted me to incorporate their locality data herein. The excellent drawing of a hypotype, from the pen of Dr. Van Mol, was graciously provided by Drs. Van Mol and Tursch. I am very grateful to my Belgian colleagues for their most cordial cooperation in this matter.

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## Intraspecific Evolution in *Blasicrura interrupta* (GRAY)

(Gastropoda : Cypraeidae)

BY

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(3 Text figures; 1 Map)

THE COWRIE SPECIES *Blasicrura interrupta* (GRAY, 1824) evidently originated in Indonesia where its ancestors, the Pliocene *B. insculpta* (MARTIN, 1899) and *B. nikinikiensis* (SCHILDER, 1928) have been found and its Recent ally *B. quadrimaculata* (GRAY, 1824) has its center of distribution (see SCHILDER, 1941, p. 99). The Recent *B. interrupta* (in the broad sense) occupies the area between Sharks Bay, Ceylon, Okinawa, Palau Islands, Samoa, Tonga, and the southern Capricorn Islands; one beach shell is said to have been collected in the Lord Howe Islands in 1962 (ex coll. R. J. Griffiths sent by Ray Summers to the writer for examination; see below).

### TAXONOMY

This area is rather large; therefore it seems to be less probable that the species has remained uniform in all areas from Ceylon to Tonga, than that it has differentiated into geographical or ecological intraspecific taxa with restricted habitat. In fact, nine taxa have been established; they are enumerated in the following list in chronological order; additional good figures have been cited in parentheses (); the type localities in brackets [] have been quoted from SCHILDER, 1966 b, p. 229.

*Cypraea interrupta* GRAY, 1824, *Zool. Journ.* 1: 376, (1870, SOWERBY, *Thes. Conch. Cypr.* figs. 271-272; 1966, *The Veliger* 8, plt. 44, fig. 64); [Ceylon]

*Cypraea quadrimaculatae* varietas *pallidula* GASKOIN, 1849, *Proc. Zool. Soc. London* 1848: 97 (1870, SOWERBY, *Thes. Conch. Cypr.* fig. 275; 1966, *The Veliger* 8, plt. 44, figs. 63, 65); [Philippines]

*Cypraea rhinoceros* SOUVERBIE, 1865, *Journ. de Conchyl.* 13: 156, plt. 5, fig. 1 (1870, SOWERBY, *Thes. Conch. Cypr.* figs. 273, 274, 535; 1964, *The Veliger* 6, plt. 25, fig. 33) [Art Island (New Caledonia)]

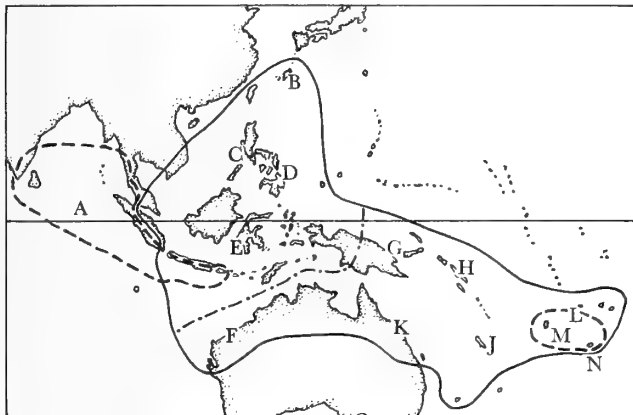
*Cypraea prestoni* SHAW, 1909, *Proc. Malacol. Soc. London* 8: 299 (nom. nov. pro *C. interrupta* GRAY) [Ceylon]  
*Blasicrura* (*Blasicrura*) *pallidula simulans* SCHILDER & SCHILDER, 1940, *Arch. Molluskenk.* 72: 43 (C. CATE, 1964, *The Veliger* 7: 19, not figured) [Sharks Bay]

*Blasicrura rhinoceros vivia* STEADMAN & COTTON, 1943, *Proc. South Austral. Mus.* 7: 323 (not figured) [Suva, Fiji]  
*Bistolida* (*Blasicrura*) *pallidula summersi* SCHILDER, 1958, *Arch. Molluskenk.* 87: 85, fig. 6 (1964, *The Veliger* 6, plt. 25, fig. 34) [Nukualofa (Tongatabu)]

*Cypraea* (*Blasicrura*) *pallidula luchuana* KURODA, 1960, *Cat. Moll. Okinawa*, p. 74, plt. 3, figs. 40-45 (1963, *The Veliger* 5, plt. 15, fig. 2) [Okinawa]

*Cypraea (Blasicrura) dayritiana* CATE, 1963, The Veliger 5: 141, plt. 15, figs. 1, 3 (1966, The Veliger 8, plt. 44, fig. 62) [Marily Island, Coron Bay (Philippines)]

As the characters of these taxa pass each into the other, they should be regarded as parts of one species only; it must be called *interrupta* by law of priority, though the geographically central and phylogenetically primary taxon is *pallidula*. There are, however, three taxa which are rather distinct morphologically though overlapping geographically (see the Map) so that they should be classified



----- borders of the proiespecies *interrupta* in the West and *summersi* in the East

———— borders of the proiespecies *pallidula*

..... borders between the Western and Eastern branches of proiespecies *pallidula*

at least as **proiespecies** (according to SCHILDER, 1966 a, p. 184), viz. the western *interrupta*, the central *pallidula*, and the south-eastern *summersi*. While the western and the south-eastern proiespecies living on the verge of the whole area of distribution of the species are confined to relatively small areas, the central *pallidula* occupies a large area, so that it has branched into three **subspecies**: the northern *luchuana*, the central *pallidula* and the eastern and southern *rhinoceros*. The two last named subspecies may be divided each into two taxa of lower though still subspecific rank according to the International Rules of Zoological Nomenclature, called **infraspecies** (by SCHILDER, 1966 a, p. 185), viz. *pallidula* into a possibly ecological local variant *dayritiana* in the north, and the widely distributed typical *pallidula*; and *rhinoceros* into the West Australian *simulans* and the eastern *rhinoceros* almost only on zoogeographical reasons. Besides, the infraspecies *pallidula* and *rhinoceros*, and the proiespecies *sum-*

*mersi* provisionally can be divided into several **unnamed groups** according to their habitat. The names *prestoni* and *vivia* should not be used: the former is an absolute synonym of *interrupta* established on the erroneous assumption that GRAY's name was preoccupied by a *nomen nudum*, the latter designates typical *rhinoceros* from Fiji.

It seems desirable to designate the lowermost units by the letters A to N, so that the species *interrupta* may be classified as follows (p = proiespecies, s = subspecies, i = infraspecies):

- A (p) *interrupta* (= *prestoni*) Ceylon to Puket Island, south coast of Sumatra and Java, Bali
- (p) *pallidula*
- B (s) *luchuana* Ryukyu Islands (Okinawa)
- (s) *pallidula*
- C (i) *dayritiana* Coron Bay (Philippines); Okinawa?
- (i) *pallidula*
- D ex Philippines North Borneo to Palau Islands and Menado
- E ex Indonesia Singapore and South Java to Western New Guinea
- (s) *rhinoceros*
- F (i) *simulans* North West Australia to Sharks Bay
- (i) *rhinoceros*
- G ex Bismarck Archipelago (not yet known from Eastern New Guinea)
- H ex Solomon Islands (not yet known from the New Hebrides)
- J ex New Caledonia and Loyalty Islands
- K ex Queensland to Capricorn Islands; Lord Howe Island
- L ex Fiji (= *vivia*) to Wallis Island, Samoa, and rarely Tonga
- (p) *summersi*
- M ex Fiji (and Samoa?)
- N ex Tonga

## CHARACTERS OF THE SHELLS

The seven named taxa can be distinguished generally according to the following key:

- 1 Teeth very fine and numerous, short; dorsum with three broad zones the central of which may be slit ..... (p) *interrupta*
- Teeth coarser and less numerous, more produced; dorsum with four narrow distant zones which often become indistinct ..... 2
- 2 Teeth less distant; shell mostly rather broad: ..... (p) *pallidula* ..... 3

- Teeth very distant; shell slender, especially in front  
..... (p) *summersi*
- 3 Spire blotch mostly distinct, blackish; fossula flattened ..... (s) *luchuana*
- Spire blotch absent (protoconch only blackish);  
fossula concave ..... 4
- 4 Anterior extremity constricted; margins unspotted  
..... (s) *pallidula* 5
- Anterior extremity broad, dorsally callous; margins  
often finely spotted (s) *rhinoceros* ..... 6
- 5 Shell very broad, callous; columellar teeth produced almost to the outer margin .... (i) *dayritiana*
- Shell rather slender; columellar teeth less produced, attaining about the center of the lip .....  
..... (i) *pallidula*
- 6 Generally larger and more slender; from West Australia ..... (i) *simulans*
- Generally smaller and broader, callous; from the Pacific ..... (i) *rhinoceros*

However, the exact determination of many shells from unknown habitat is often impossible, though extremes always are well recognizable: for the indicated characters are rather variable.

The quantitative, *i. e.* the measurable characters have been tabulated in Table 1: the columns indicate *n* = the number of examined shells, *L* = the length (in mm), *BL* = the relative breadth (in % of the length), *LT* and *CT* = the relative closeness of labial teeth and of columellar teeth respectively (both expressed by letters according to the tables published in SCHILDER, 1958); in each column, the two marginal figures express the limits of the "usual variation," *i. e.* the limits of two thirds of specimens most approaching the median (see SCHILDER & SCHILDER,

1966c, p. 209), the central figure (in parentheses) indicates the median itself which approaches the mean between the lower and upper limits of the usual variation.

In diagram Figure 1 the length has been plotted against the relative breadth; the letters A - N indicate the mean between the limits of usual variation (not the median of all specimens); the circles around the centers A, B (cross-hatched), C, M + N, and X (*i. e.* the sum of D to

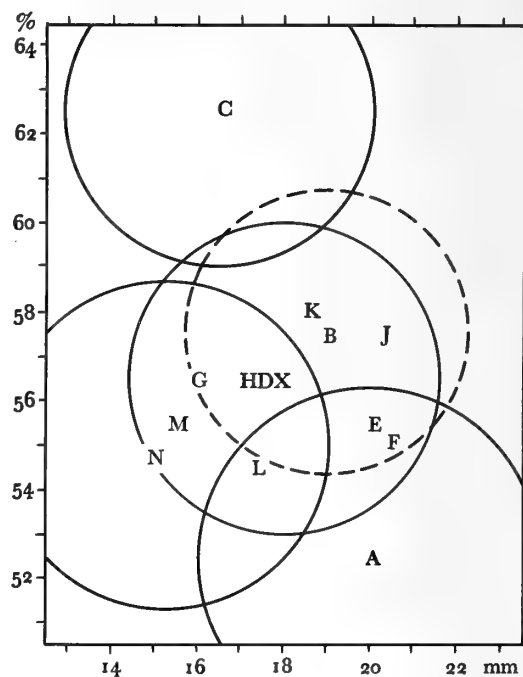


Figure 1

Table 1

		<i>n</i>	<i>L</i>	<i>BL</i>	<i>LT</i>	<i>CT</i>
<i>Blasicrura</i>						
<i>interrupta</i>	A	409	17(20)23	51(52)54	s(u)w	s(u)w
<i>luchuana</i>	B	37	17(19)21	56(57)59	o(p)q	o(p)r
<i>dayritiana</i>	C	19	15(16)18	60(63)65	m(m)n	l(n)p
<i>pallidula</i>	D	21	15(17)20	55(56)58	p(q)s	n(p)r
<i>pallidula</i>	E	24	17(20)23	54(55)57	o(q)r	m(o)q
<i>simulans</i>	F	12	17(20)24	54(55)56	q(r)t	n(p)r
<i>rhinoceros</i>	G	580	14(16)18	55(57)58	q(r)t	p(r)s
<i>rhinoceros</i>	H	33	15(17)19	55(56)58	q(r)s	o(q)s
<i>rhinoceros</i>	J	44	18(21)23	56(57)59	q(r)s	o(p)r
<i>rhinoceros</i>	K	68	16(18)21	56(57)60	p(r)s	n(p)r
<i>rhinoceros</i>	L	22	15(18)20	52(55)57	r(s)t	o(q)r
<i>summersi</i>	M	142	14(15)17	53(55)58	o(p)q	i(k)m
<i>summersi</i>	N	27	13(15)17	52(54)57	o(o)p	i(i)i
Mean of 13 areas A - N			16(18)20	55(56)58	p(q)s	n(p)q

L) comprise two thirds of specimens most closely approaching these centers, as they pass through the crossing points of the limits of usual variation in each direction (see SCHILDER, 1966e). One will observe that three taxa indicate the corners of a triangle: the prospecies *interrupta* (A) is large and narrow, *summersi* (M+N) is small and rather narrow, and *dayritiana* (C) is extremely broad; the other taxa are rather crowded in the central area, but there are some evident peculiarities: the western E and F tend to the still more western A, and the eastern populations of *rhinoceros* (L) tend to *summersi* (M+N) inhabiting the same area; among the remaining taxa those inhabiting the peripheral areas (B, J, K) are larger than their equatorial allies (D, G, H), as it is in other cowries too (see SCHILDER, 1961).

In diagram Figure 2 the closeness of labial teeth has been plotted against the columellar teeth in the same manner. There is a similar triangular arrangement of extremes concerning the same taxa A, M+N, and C, though they are placed in a different way: *interrupta* (A) has very numerous teeth on both lips, and *summersi* (M+N) has very few, so that the circles indicating the limits of usual variation hardly cross the central circle containing all remaining taxa which are still more crowded (their common center coincides with J); the third corner (C) is less striking and refers mostly to columellar teeth.

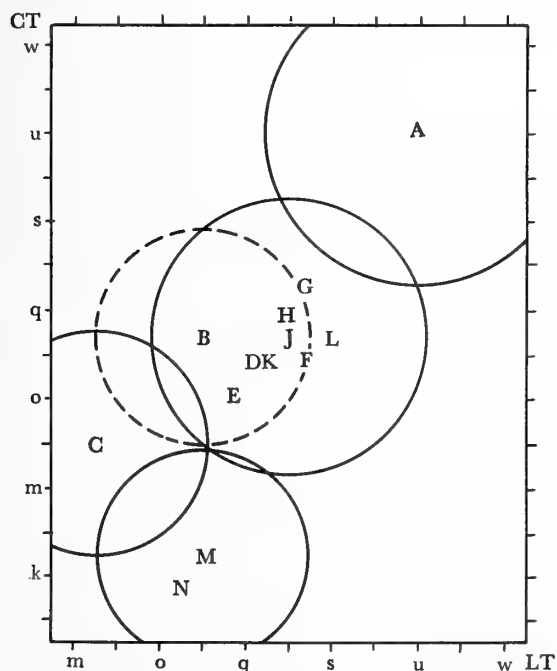


Figure 2

The main qualitative, i. e. not measurable characters distinguishing intraspecific taxa of the species *interrupta* are explained below; the figures 1 to 3 indicate different degrees in development of the character concerned:

AE = anterior extremity: 1 = rather constricted, mostly white, to 3 = broadly rounded with a distinct nose-like callosity which is mostly grey.

CT = columellar teeth: 1 = short, not attaining the center of the lip; 2 = more produced so that they cross the center; 3 = crossing the lip almost to the outer margin.

Fo = fossula: 1 = narrow, shallow to 3 = rather broad, concave.

Zo = two central zones: 1 = absent to obsolete, distant; 2 = distinct, distant, narrow, continuous to hardly interrupted; 3 = broad, approaching each to the other, connected by a less darkly colored area or even quite confluent so that there is one central zone only which mostly becomes dissolved into rather longitudinal spots as are the terminal zones also.

Sp = spire blotch: 1 = always absent; 2 = rarely indistinctly indicated; 3 = well developed in about two thirds of specimens. The black spire blotch is situated on the right side of the spire, and it must not be confused with the blackish protoconch, visible in many shells of all intraspecific taxa of *interrupta*.

LS = lateral spots: 1 = always absent; 2 = mostly present though scarce and small; 3 = numerous, well visible.

The prevalent formation of these six qualitative characters of structure and color has been indicated in Table 2.

Table 2

		AE	CT	Fo	Zo	Sp	LS
<i>Blasicrura</i>							
<i>interrupta</i>	A	3	1	2	3	1	1
<i>luchuana</i>	B	1-2	2	1-2	1	3	1
<i>dayritiana</i>	C	1	3	2	1	2	1
<i>pallidula</i>	D	2	2	2	2	1	1
<i>pallidula</i>	E	2	2	2	2	1	1
<i>simulans</i>	F	2-3	2	3	2	1	2
<i>rhinoceros</i>	G	3	2	3	2	1	2
<i>rhinoceros</i>	H	3	2	3	2	1	2
<i>rhinoceros</i>	J	3	2	3	2	1	3
<i>rhinoceros</i>	K	3	2	3	2	1	2
<i>rhinoceros</i>	L	3	2	3	2	1	2
<i>summersi</i>	M	1	3	1	1-2	1	1
<i>summersi</i>	N	1	3	1	1-2	1	1-2

Other qualitative characters seem to be less important, e. g. the closeness of the dorsal specks, the presence of a pale dorsal line, the degree and the direction of the interruptions of the dorsal zones (which often look more interrupted in worn shells than in fresh specimens), the development of the grey spot above the anterior extremity (which becomes well marked in races with callous extremity and is dark brown in worn shells), the dull base (said to be a character of *dayritiana*); the existence of small terminal spots chiefly on the right margin of the anterior extremity seems to be peculiar to *summersi* (it has been interpreted as beginning of the typical spots of *Blasicrura quadrimaculata*).

The only shell said to come from Lord Howe Islands (see above) is large (23 mm), broad (64%), with rather distant teeth (class n:n); it is callous with attenuated extremities, the columellar teeth cross only half the lip, the much worn dorsum exhibits two distant central zones, each dissolved into three small square spots; it possibly may be intermediate between *Blasicrura rhinoceros* and *B. summersi*, but as its formula does not fit to the diagrams 1 and 2, it possibly constitutes a new southernmost local race.

### CHARACTERS OF THE ANIMALS

The animal's color has been said to be different in *rhinoceros* and *summersi* (CERNOHORSKY, 1966, pp. 196, 197) as well as Mrs. H. Minzak (*in litt.*) discovered differences between the true *luchuana* (animal black) and specimens from Okinawa without the spire blotch (animal grey with white spots). These indications, however, seem to be very questionable, as my own examination of specimens (preserved in alcohol) showed great variation within the races and no consistent differences between the races nor the sexes: in 6 *Blasicrura luchuana* from Okinawa (with or without spire blotch), 2 *B. rhinoceros* from Queensland and 2 *B. summersi* from Fiji the mantle varies from grey to black with or without pale appendices, and the sides of the foot vary from pale fulvous marbled with dark specks in various degrees to entirely black; the animal of the only young specimen (*B. summersi*) was even dark carmine.

The radula, however, shows remarkable differences, so far as the ten examined radulae permit one to form an opinion. In the six *Blasicrura luchuana* from Okinawa with or without a spire blotch (5 ♀ ♀, 1 ♂) the anterior edge of the median tooth shows 3 denticles, and that of the admedian tooth shows also 3 denticles only, as it is in *B. quadrimaculata* (GRAY), too. On the other hand, in the 2 *B. rhinoceros* (♀ and ♂) and in the 2 *B. summersi* (♂ and young) the median shows 5 denticles, and the admedian shows 4 denticles, as it is in *B. coxeni* (Cox). Besides, in all specimens from Okinawa the lateral teeth are rather broad and hook-like, with coarse denticles,

while all specimens from Queensland and Fiji show the laterals very slender with weak denticles on the tip; these differences are comparable to those observed in the genus *Staphylaea* (see SCHILDER & SCHILDER, 1966 d, where figure 1 recalls *B. luchuana* though in the latter the lateral denticles are coarser, whereas figure 2 recalls *B. rhinoceros* and *B. summersi*); but in *Staphylaea* this dimorphism is rather sexual, while the differences in *Blasicrura interrupta* could be racial. It is to be regretted that the radula of the western *B. interrupta*, the Malayan *B. pallidula* and the typical Melanesian *B. rhinoceros* is still unknown.

### EVOLUTION

According to the characters discussed above, the probable intraspecific evolution of *Blasicrura interrupta* could be outlined as follows (see Figure 3):

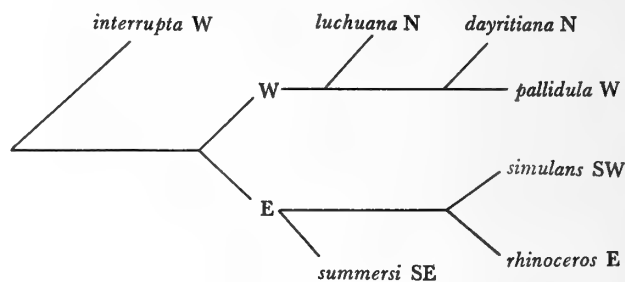


Figure 3

1. The common ancestor is believed to recall the present Malayan *Blasicrura pallidula* which is intermediate morphologically and central geographically.

2. First of all, *B. interrupta* separated on the western border of the inhabited area, by the teeth becoming finer and the dorsal zones approaching each other; these characters became stabilized genetically so that this representative of the Indian province may be regarded almost of specific rank as it overlaps, in southern Java, the area of *B. pallidula* mostly living in the Pacific province.

3. Within the latter branch, the separation of a western group (*B. pallidula*) and an eastern group (*B. rhinoceros*) evidently dates from less old times, though the morphological differences in the radula and lateral spots seem to be rather constant.

4. In the eastern group, *B. summersi* separated in early times on its south-eastern border; though its characters (distant teeth, shallow fossula) are far less striking, *B. summersi* must have been stabilized genetically so that a few true *B. rhinoceros* now can intrude into its area without causing evident hybrids.



5. The separation of *B. luchuana*, however, on the northern border of *B. pallidula* must be far younger, as its chief character (the black spire blotch) is developed in only two thirds of specimens in the restricted area of the Ryukyu Islands; one third is hardly distinguishable from the Malayan *B. pallidula*.

However, if one restricts *luchuana* to such specimens coming from Okinawa which exhibit the spire blotch, then *luchuana* should be regarded as a conspecific contemporary with *summersi*, as it becomes overlapped by the Malayan *pallidula*; the medians of the measurable characters (Table 1) of the restricted *luchuana* do not become altered.

6. The status of the recently discovered *B. dayritiana* is still uncertain: it may be an ecological variety only of *B. pallidula*, as similar shells seem to occur also in Okinawa, or a recent local mutant just beginning to spread in the north of the area inhabited by *B. pallidula* and *B. luchuana*.

7. The establishing of *B. simulans* can hardly be justified by morphological reasons; but as it is probable that, like in other cowries, the isolated West Australian populations became genetically different from the eastern *B. rhinoceros*, *B. simulans* may be regarded as the youngest separable unit on zoogeographical grounds.

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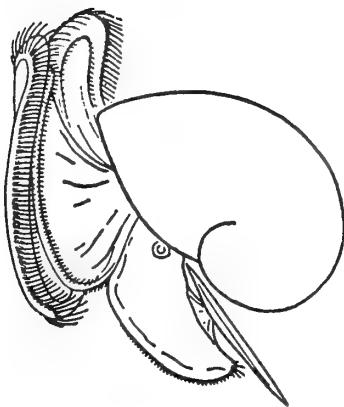
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## Bryozoan-Mollusk Relationships

BY

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(Plate 40)

THE NATURE OF BRYOZOAN-MOLLUSK relationships has received considerable attention within the past four decades (BALSS, 1924; LECOINTRE, 1929, 1933; DOUVILLE, 1931; ROGER & BUGE, 1948; OSBURN, 1957; DUNCAN, 1957). The results of most of these earlier investigations were, however, contradictory. In general, two opposing schools of thought have developed. The first regards bryozoan-mollusk associations as primarily fortuitous, while the other maintains that bryozoan species are very specific in their choice of a substrate. Proponents of this latter view (DUNCAN, 1957; MOORE, 1963) have generally advocated that each particular bryozoan species is capable of successfully encrusting one species of mollusk only and that most bryozoan-mollusk associations are either symbiotic (BUGE, 1952), commensal or amensal (DUNCAN, 1957).

OSBURN (1950, 1957) was perhaps the most vociferous proponent of the first view. He stated (1957, p. 1109), that bryozoans ordinarily show little "choice" of a substratum, and that, in general, any firm and clean object will serve. He observed (*op. cit.*, p. 1110) over 30 species of bryozoans attached to a single large *Pinna* shell, and also pointed out that CANU & BASSLER determined more than 90 species from a single bryozoan haul.

DEICHMANN (1954) after studying the bryozoans encrusting the "Texas longhorn shells" from the Florida waters similarly concluded (DEICHMANN, *op. cit.*, p. 77) that the bryozoans were independent of mollusk shells as substrates. These records are, however, not compatible with views expressed by a larger number of other authors who have generally argued in favor of the host-specificity of most bryozoan species.

DUNCAN (1957) recently published an excellent summary of our knowledge of fossil bryozoans and devoted considerable attention to a discussion of the nature of their biotic associations. She concluded (*op. cit.*, p. 789)

that certain bryozoan species "almost invariably incrust only one kind of shell", and that the ability of a bryozoan species to completely enclose the encrusted substrate was indicative of the fact that the substrate was animate and mobile. A similar view was expressed by MOORE (1963, p. 88; pl. 32, fig. 1), who reported a "*Membranipora* sp." that forms a coating as much as nine millimeters in thickness on the gastropod *Searlesia? carlsoni* (ANDERSON & MARTIN, 1914) in the Astoria Formation of Oregon. She observed that the bryozoan was not found encrusting any other gastropod, although *Priscofusus medialis* (CONRAD, 1865) occurred in close association, in a similar environment and seemed to offer the same relative shape.

The problem of host specificity was carried a step farther by KIRKPATRICK & METZELAAR (1922) who described a *definite*, beneficial association between the multilamellar bryozoan species, *Conopeum commensale* KIRKPATRICK & METZELAAR, 1922, and the hermit crab *Petrochirus granulimanus* MIERS (= *Pagurus granulimanus* (MIERS)). They affirmed that the bryozoan-hermit crab association "appears to be a *definite* and not an accidental one, the crustacean and Polyzoon being more to each other than casual messmates; for it is certain they derive special advantages from each other's presence ... the Polyzoon obviously benefits; for it is in alliance with a vigorous and successful marauder, and although sedentary by nature, is continually being carried to new and rich pastures." Because these authors failed to observe the bryozoan species on living mollusks from the same locality, they tentatively concluded (*op. cit.*, p. 988) that the bryozoan can possibly survive only for a short time and with much diminished vitality on an untenanted gastropod shell.

Data currently being assembled by the writer (though presently incomplete) are yielding very interesting results that tend to show that cheilostomatous bryozoans, at least, are not host specific. The author has confined his attention to a study of multilamellar cheilostomes only

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(see Plate 40). The advantage of this approach is that it is possible to observe not only the diversity of hosts incrustated by any single species but also the nature of the relationship of the many-layered colony of zooecia to the encrusted host. The latter can be more accurately inferred only by studying the large overgrown forms.

The materials in the collections of the Museum of Paleontology, University of California, Berkeley, currently being studied by the writer, include several large, ball-like, multilamellar colonies ranging in age from the Late Miocene (Santa Margarita Formation) to the Recent. The largest of these are over 2 inches in diameter (see Plate 40, Figures 3 and 5). By studying the gross morphology and thin sections of a few of these it is possible to make a few valid inferences. These preliminary results and their relationship to previously published views (discussed earlier) are discussed briefly below.

- 1) It was observed that at any single locality, members of a single bryozoan species encrust a diverse array of substrates. Such diverse substrates encrusted include different genera and species of gastropods (Figures 4 and 5), pelecypod shell fragments (Figures 1 and 2), and coarse-grained, arkosic sandstone fragments (Figure 3). This observation is, thus, in support of views earlier expressed by OSBURN (1957, p. 1109), but contradicts DUNCAN's (1957) and MOORE's (1963) idea that most bryozoan species incrust one kind of shell only.
- 2) In species that encrust gastropod shells, various stages representing gradual but continuous closure of the aperture is demonstrable (see Figures 4 and 5). Though the earliest formed zooecial layers follow the irregular contour of the encrusted substrate faithfully (see Figures 1 and 3), the tendency is for the bryozoan mass to finally assume a spherical shape (Figures 3 and 5). This observation indicates that while it is possible for a bryozoan to encrust an initially living shell, continued existence of the living mollusk is not required for continued thriving of the bryozoan. The implications of this observation are further discussed below. The tendency for the bryozoan to smother the host, overgrow its aperture and assume a spherical shape indicates that the relationship between them is certainly not advantageous to both.
- 3) The bryozoans tend to cover the encrusted substrate completely (Figures 1 to 5) irrespective of the fact that such substrate was initially animate (pelecypod and gastropod), or inanimate (shell fragment and sandstone fragment). This is, by far, the most important observation. DUNCAN (1957, p. 789) contended that the fact that bryozoans could completely cover an encrusted shell was good evidence that the former encrusted only

the shells of living mollusks. Her conclusion is, however, negated by the fact that these bryozoans encrust not only whole (Figure 2), but fragmentary shells (Figure 1) which could not have been part of a living mollusk when it was initially encrusted. The same bryozoan species also encrusts and completely encloses inanimate sandstone fragments (Figure 3). Additionally, these colonies appear to thrive equally well on molluscan as well as on sandy substrates (Figures 3 and 5). From this, it is possible to infer that not only have the bryozoans no need for an animate substrate at the start but also that any animate object that is initially encrusted or that secondarily inhabits such encrusted substrate (such as hermit crabs in gastropod shells) will eventually be smothered. Thus, the hermit crab inhabiting an encrusted gastropod shell will either get sealed within the shell by the rapidly expanding bryozoan or will escape before being sealed in, to find another shell. Even if we assume that the hermit crab is capable of keeping the molluscan aperture free by actively removing new zooecia deposited across it, its association with the bryozoan appears to be far from advantageous.

Thus, the author's present study tends to indicate that cheilostomatous bryozoans are not substrate-specific. The same species indiscriminately encrusts a diverse array of animate and inanimate objects. Bryozoan species can completely enclose a substrate even if the latter is non-animate. Finally, it is very likely that bryozoan-mollusk relationships are, at best, only fortuitous. Their reported restriction to one particular type of host or substrate is probably an oversight caused by inadequate sampling.

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## Explanation of Plate 40

Membraniporid Bryozoans (? *Conopeum* spp.) Encrusting Diverse Substrates.

Figure 1: Hypotype, Univ. Calif. Mus. Paleo. no. 12160, x 2. Locality A-742. Late Miocene, Santa Margarita Formation, La Panza Quadrangle, San Luis Obispo County, California. "From south  $\frac{1}{4}$  corner of Sec. 9, T. 29S., R. 17E." Thin section of a bryozoan colony encrusting a fragment of a pectinid shell. Note disc-like shape of colony and the undulations coinciding with the position of ribs. Parts of the outer edge of the specimen were lost during preparation. - Figure 2: Hypotype, UCMP no. 32886, x  $\frac{3}{4}$ . Locality B-6411. Pleistocene, San Pedro Formation, San Pedro Quadrangle, Los Angeles County, California. Collected from sandstones halfway between Harbor Freeway and Gaffey Street, about 100 to 300 feet south of Union Oil Refinery, San Pedro, California. Massive colony completely encrusting a valve of the pelecypod *Pseudochama exogyra* (CONRAD, 1837). Other colonies of the same species encrusting different gastropod shells were collected from the same locality. - Figure 3: Hypotype, UCMP no. 12159, x 2. Locality A-741. Late Miocene, Santa Margarita Formation, La

Panza Quadrangle, San Luis Obispo County, California. From Waterfalls, near the county road in the S. W.  $\frac{1}{4}$  of Sec. 22, T. 29S. R. 17E. Thick succession of zooecial layers encrusting an irregular arkosic sandstone fragment. Note that, as in Figure 1, earliest formed layers follow the irregular topography of the encrusted surface. - Figure 4: Hypotype, UCMP no. 32883, x 0.9. Locality A-4454. Recent, Tumaco, Colombia, South America. Collected between Tumaco and the mouth of Rio Rosario. Massive colony encrusting an *Epitonium*-like gastropod. Note that aperture is still open but shows evidence of continued closure by zooecia. - Figure 5: Hypotype, UCMP no. 12158, x 1  $\frac{1}{2}$ . Locality A-9731. Late Miocene, Santa Margarita Formation, Joaquin Rocks Quadrangle, Fresno County, California. From an orange to buff, sand and clay bed with abundant sand-filled borings on the bank of Domingine Creek in the N. W.  $\frac{1}{4}$  of the S. W.  $\frac{1}{4}$  of Sec. 33, T. 18 S., R. 15E. Massive colony completely enclosing a gastropod shell over whose aperture a zooecial layer over one inch thick was formed.



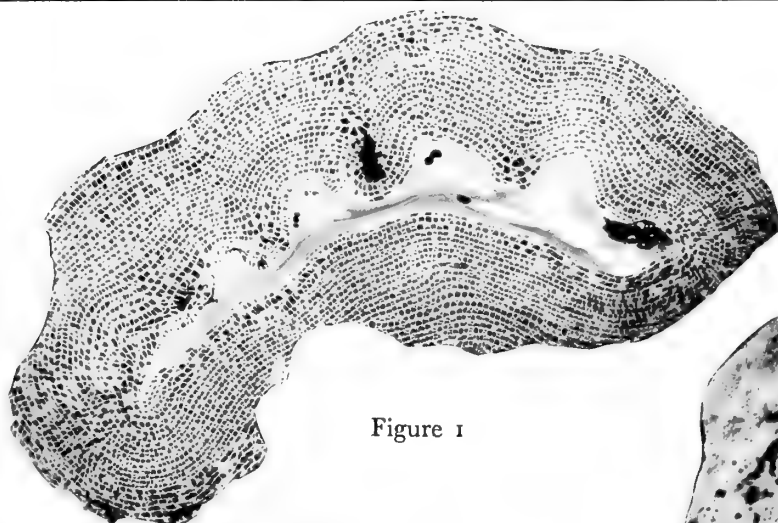


Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



# A New Subspecies of *Volutoconus hargreavesi* (ANGAS, 1872) from Central Western Australia

(Gastropoda : Volutidae)

BY

CLIFTON STOKES WEAVER

Honolulu, Hawaii

(Plate 41; 1 Map)

DURING THE 1960 Hawaiian-Western Australian Expedition, of which I was a member, we dredged the first recorded living *Volutoconus hargreavesi* (ANGAS, 1872) from 23 fathoms off Bezout Island, Dampier Archipelago, north Western Australia (Plate 41, Figures 3, 4). Several weeks earlier and a thousand miles south of Dampier, we had examined a shell (Plate 41, Figure 7) collected in the Houtman Abrolhos Islands (45 miles west of Geraldton) and found that it differed sculpturally from the northern *V. hargreavesi* to such a degree that it appeared to be a new species of volute (WEAVER, 1960).

About this time, Dr. Donald F. McMichael was working on *Volutoconus grossi* (IREDALE, 1927) from the east coast of Australia. In his investigation, McMICHAEL (1960) found that the shell of *V. grossi* exhibited a considerable amount of sculptural variation along its north-south coastal range, particularly with respect to the presence or absence of nuclear ribbing. This ribbing is obscured by a nacre glaze in southern populations. A further difference, not reported by McMICHAEL, appears to be the almost total lack of a raised columellar callus just above the fourth posterior plait, in the northern form from off Townsville, Queensland. He subsequently named this population *Volutoconus grossi helenae* McMICHAEL, 1966, in honor of his wife.

In the years following our 1960 Expedition, more shells turned up on the west coast representing both the northern *Volutoconus hargreavesi* and the southern Houtman Abrolhos Islands form, including a live specimen of the latter trawled by Will Goode from 118 fathoms off Point Cloates (Plate 41, Figures 8, 9).

Keeping McMICHAEL's observations in mind and with these additional specimens to study, it became apparent that the southern shells from the Houtman Abrolhos Islands north to North West Cape represented a popu-

lation which differed consistently in sculpture from *Volutoconus hargreavesi*. Up to the time of this writing, no intergradation has been observed.

I, therefore, propose to establish this southern population as a new subspecies of *Volutoconus hargreavesi* (ANGAS, 1872).

Before describing this subspecies, I will briefly outline the genus and nominate subspecies that are involved.

## *Volutoconus* CROSSE, 1871

1871. *Voluta* (*Volutoconus*) CROSSE, Journ. Conchylol. 19: 306 (Raised to full generic rank by McMICHAEL, 1960).

Type Species: *Voluta coniformis* Cox, 1871; Recent, Australia; by monotypy.

So far as is presently known, the genus is restricted to east, north and west Australian waters.

The single most outstanding morphological characteristic of the four species and two subspecies comprising the living representatives of this genus is the needle-like spur or calcarella which protrudes from the first whorl. However, according to McMICHAEL (1966): "The significance of this structure, from the taxonomic point of view, is uncertain since *Volutoconus* does not seem to be related in anatomy or radular structure to the Scaphelloides." The Scaphelloides, from the Western Atlantic off Florida, have a similar calcarella.

Shells moderately large, solid, either with dark chocolate revolving and axial bands on a cream-colored background as in *Volutoconus bednalli* (BRAZIER, 1879) or brightly colored in yellowish-orange and orange-red with white triangular designs. Spire may be elevated (*V. grossi*

and *V. hargreavesi*) or depressed (*V. coniformis*) and the nucleus may show radial ribbing or the ribbing may be covered over by a nacre glaze (southern *V. grossi* and northern *V. hargreavesi*). Post-nuclear and body whorls may be longitudinally plicate (southern *V. hargreavesi*) or relatively smooth (northern *V. hargreavesi*). Columella with 4 to 5 plaits. Radula, where known (*vide* ABBOTT, 1958), uniserial with 35 to 40 large, tricuspid teeth.

*Volutoconus hargreavesi hargreavesi* (ANGAS, 1872)

(Plate 41, Figures 1 to 4; Map)

1872. *Voluta hargreavesi* ANGAS, Proc. Zool. Soc. London, p. 613, pl. 42, fig. 13 (no locality given)

1960. *Volutoconus hargreavesi* (ANGAS, 1872), WEAVER, Hawaiian Shell News 8 (11): 1, 3 (two shells top left, two shells bottom left)

Holotype: American Museum of Natural History, New York (AMNH no. 8304)

Type Locality: Bezout Island, Dampier Archipelago, north Western Australia, where the first living specimen was collected, designated by WEAVER, 1960

Range: Dampier Archipelago, south to Long Island in Exmouth Gulf, north Western Australia. Appears to inhabit moderately deep water. Only recorded live specimen taken in 23 fathoms.

Shell Description: Shell solid, of medium size (at least 88.3 mm in length), either narrow or somewhat bulbous. Nucleus smooth, of about 4 whorls, with needle-like calcarella protruding from apex. Second and third nuclear whorls white, rest of nucleus orange. Surface of shell longitudinally sculptured with closely spaced growth lines. A slight bulge at shoulder of each whorl. Color bright orange-red with white triangular markings showing

through, principally in 3 bands: one at periphery of body whorl, one below suture and another at anterior tip. Columella straight with four well developed plaits. Aperture white, siphonal notch deep.

In his original description ANGAS stated that there were 3 columellar plaits. This is an error; I have examined the holotype and it has 4 plaits, as do all others of the northern *Volutoconus h. hargreavesi* that I have seen.

Unfortunately, the animal taken during the 1960 Hawaiian-Western Australian Expedition was found to be damaged when extracted from the shell (McMichael, *in litt.*) and as a result we cannot make a report here on anatomical features of this subspecies.

Remarks: As far as is presently known, this is the first time that photographs have ever been published of the holotype of *Volutoconus h. hargreavesi*.

*Volutoconus hargreavesi daisyae* WEAVER, subsp. nov.

(Plate 41, Figures 5 to 9; Map)

Shell Description: There are two outstanding diagnostic shell characteristics associated with this southern subspecies that appear in every specimen I have seen which distinguish it from the northern *Volutoconus h. hargreavesi*. The first and most important one is the presence of a fifth weak posterior columellar plait, more deeply recessed within the aperture than the remaining 4 plaits and at almost a right angle to the shell's vertical axis. The second characteristic is the presence of ribbing on the nucleus and all post-nuclear whorls.

Shell large (adult specimens from 75 mm to 125 mm in length), solid. Color a shiny pale yellowish orange overlaid with irregular white tent-like markings which form a broad band at periphery of last whorl and two interrupted bands situated immediately anterior to suture, and just posterior to basal fasciole. Spire elevated, nucleus of  $3\frac{3}{4}$

### Explanation of Plate 41

*Volutoconus hargreavesi hargreavesi* (ANGAS, 1872)

Figures 1, 2: Holotype, *ex* American Museum of Natural History, No. 8304; no locality data on original label; Height 88.3 mm, maximum diameter 39.4 mm; photographs courtesy AMNH.

Figures 3, 4: *ex* Bernice P. Bishop Museum, No. 214693; dredged alive in 23 fathoms, off Bezout Island, Dampier Archipelago, north Western Australia; Height 75.0 mm, maximum diameter 28.0 mm; photographs by Clifton Weaver

*Volutoconus hargreavesi daisyae* WEAVER, subsp. nov.

Figures 5, 6: Holotype, *ex* Delaware Museum, No. 10022; freshly dead specimen trawled in 80 fathoms southwest of North West Cape, central Western Australia; Height 85.3 mm, maximum diameter 34.3 mm; photographs by Clifton Weaver

Figure 7: Paratype no. 2; *ex* Helen Boswell coll.; taken from cray-pot in 85 fathoms; Houtman Abrolhos Islands, south Western Australia; Height 96 mm, maximum diameter 39 mm; photograph by Arch Whitworth

Figures 8, 9: Paratype no. 1; *ex* Clifton Weaver coll.; trawled alive in 118 fathoms off Point Cloates, central Western Australia; Height 85.5 mm, maximum diameter 34.0 mm; photographs by Clifton Weaver



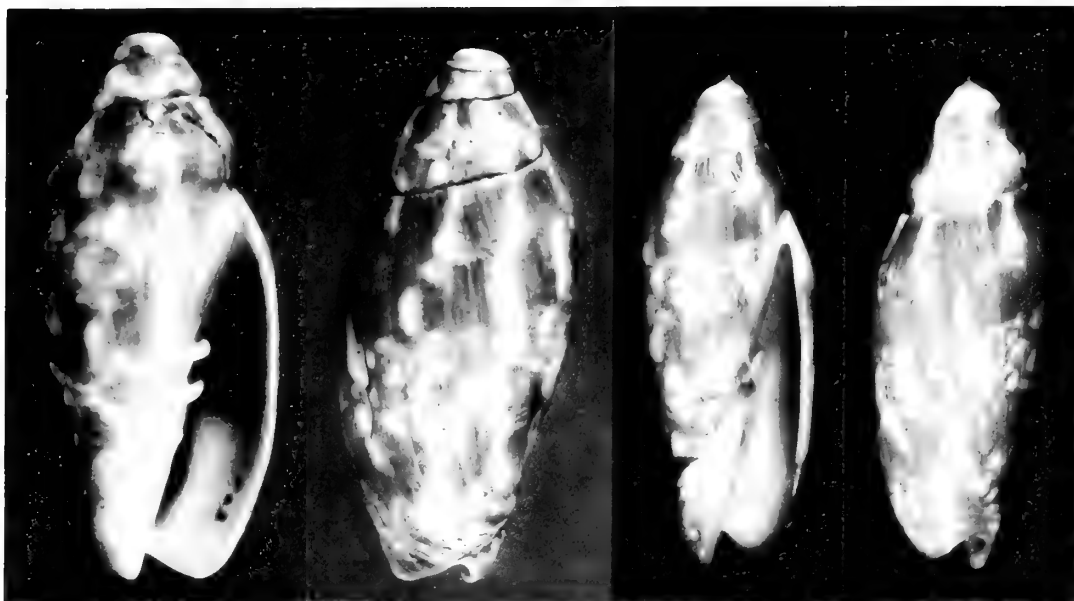


Figure 1

Figure 2

Figure 3

Figure 4



Figure 5

Figure 6

Figure 7

Figure 8

Figure 9



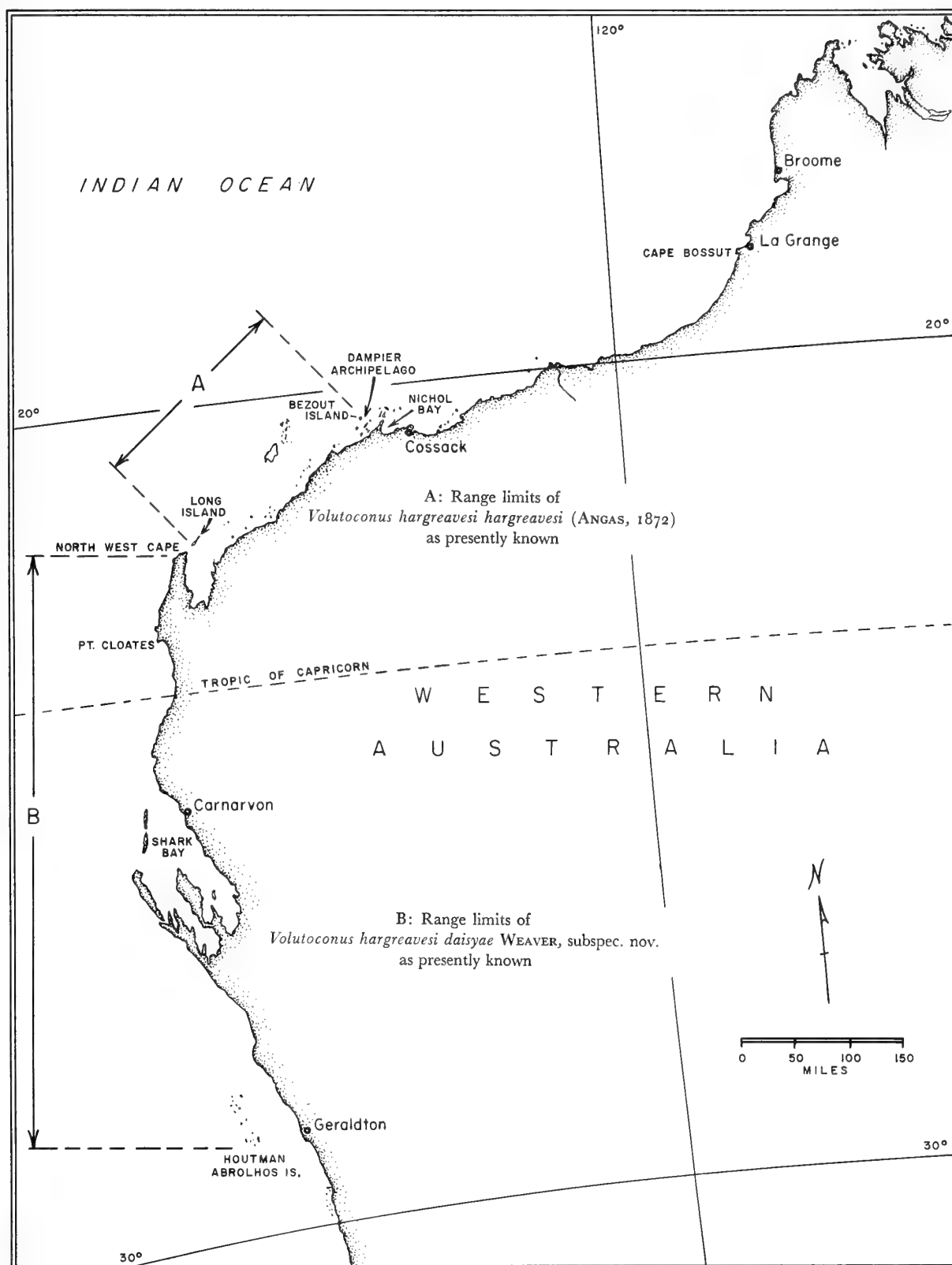


Table 1

Measurements (in millimeters) and Collecting Data  
for *Volutoconus hargreavesi daisyae* WEAVER, subsp. nov.

Specimen	Maximum Height	Maximum Diameter	Locality	Collecting Depth in Fathoms	Collector	Collection	Growth Stage	Remarks
Holotype	85.3	34.3	Southwest of North West Cape, central Western Australia	80	Will Goode	Delaware Museum of Natural History, no. 10022	Adult	Dead but fine shell taken in 1962
Paratype 1	85.5	35.0	Off Point Cloates, central Western Australia	118	Will Goode	Clifton Weaver	Adult	Live-collected, fine shell taken in 1962
Paratype 2	96.0	39.0	Houtman Abrolhos Islds., south Western Australia	85	Crayfisherman	Helen Boswell	Adult	Crab-occupied, slightly worn shell taken in crayfish-pot

to 4 whorls radially ribbed with ribs connected by fine transverse lirae. Needle-like calcarella projecting from apex. Aperture white, siphonal notch deep.

The results of an examination of the animal extracted from the single live-collected specimen have not been received from Dr. Donald McMichael at the time of this writing.

Types: The holotype has been deposited with Mr. John E. duPont for the Delaware Museum of Natural History where it bears the catalogue number 10022. Paratypes are in the collections of Clifton S. Weaver, Kailua, Hawaii and Helen Boswell, Valhalla, Transvaal, South Africa.

Type locality: Southwest of North West Cape, central Western Australia. Longitude 113° 45' East Latitude 22° 00' South.

Range: From North West Cape south to Houtman Abrolhos Islands, a distance of approximately 500 miles. The species appears to inhabit deep water, as attested to by live specimen trawled from 118 fathoms.

Remarks: As far as is presently known, this is the first time that photographs of a live-collected *Volutoconus hargreavesi daisyae* WEAVER have been published.

There are indications that the range of *Volutoconus hargreavesi daisyae* may overlap that of *V. h. hargreavesi* with no apparent intergradation taking place. If this is true, then *V. h. daisyae* should be raised to full specific rank.

I am naming this taxon for my wife, whose patience and understanding have always been a source of wonder to me.

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## Filtering Experiments on Marine Pelecypods from Tomales Bay, California

BY

DON MAURER

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FILTERING EXPERIMENTS WITH *Tellina buttoni*, *Tellina salmonea*, *Mysella tumida*, and *Transennella tantilla* have not been reported previously, although experimental work concerning the effect of turbidity, sedimentation, and substrate on mollusks is a broad field of research. Relation of filtering rates and feeding to high concentrations of micro-organisms and suspended debris has been studied primarily with *Crassostrea virginica* (GMELIN, 1790), *Venus mercenaria* (LINNAEUS, 1758), and *Mya arenaria* LINNAEUS, 1758. LOOSANOFF & ENGLE (1940, 1947), LOOSANOFF & TOMMERS (1948), CHIPMAN & HOPKINS (1954), CHIBA & OHSHIMA (1957), RICE & SMITH (1958), JORGENSEN (1960), LOOSANOFF (1962), and ARMSTRONG (1965) represent a few of the publications in the field. In Tomales Bay, California MAURER (1966) described some pelecypod-sediment associations which included *Tellina buttoni* DALL, 1900, *T. salmonea* (CARPENTER, 1864), *Mysella tumida* (CARPENTER, 1864), *Lyonsia californica* CONRAD, 1837, and *Transennella tantilla* (GOULD, 1852). The writer concluded that sediment may be a limiting factor in determining the distribution, abundance, and size of these mollusks, but that not enough was known about the biological significance of sediment to bivalves to suggest an unequivocal causal relationship. Different conclusions among workers on the response of pelecypods to turbid water and sedimentation caution against broad generalizations to other species. In view of these opinions laboratory experiments on *Tellina buttoni*, *T. salmonea*, *Transennella tantilla*, and *Mysella tumida* were performed to better understand the effect of sediment and turbidity on clams in a natural situation. The results suggest that the ability to filter a medium and the degree of ingestion of particulate material may be factors which influence the distribution and abundance of bivalves to a particular sediment type.

### METHOD

FOX, SVERDRUP & CUNNINGHAM (1937) described a method for determination of the average rate of water

propulsion through gill chambers during normal feeding, respiratory, and excretory activities of *Mytilus californianus* CONRAD, 1837. LUND (1957) used an elaborate design for silting experiments with *Crassostrea virginica* and COUGHLIN & ANSELL (1964) described a direct method for determining the pumping rate of siphonate bivalves. The author followed the general design of Fox *et al.* and used a turbidimeter as outlined by LUND.

Mollusks were maintained in an outdoor sea water table which was attached to the laboratory and was shaded from sun and rain. Algae and diatoms which grew in the containers throughout the summer provided necessary food materials. During the course of the investigation temperature was measured periodically and was found to range approximately from 13.8° to 17.0° C. Daily range in temperature within the sea water system was about  $\pm 1.5^\circ$  C. Since temperature was so stable it was not included in Table 1 with the results.

In test procedure clams were placed in beakers with sea water and different concentrations of milk, india ink, carmine, and kaolin. A control beaker of bivalves in sea water was included in each experiment. Milk was tried to determine if clearing experiments were feasible with species heretofore not considered in filtering studies. This was determined as follows. A 2 ml aliquot was removed from a beaker and placed in a Bausch and Lomb colorimeter. The colorimeter was set at 350 millimicrons. Percent transmission of light through a sample was taken as an indication of degree of clarity or turbidity of the sea water. A zero reading indicated that the water was opaque, while a 100% reading signified full transmission of light. It was observed that the mollusks cleared milk faster than it settled in the control beaker. India ink and carmine are within the size range of pelecypod food and vividly outline the digestive tract which makes them useful materials for purposes of dissection. Kaolin is composed of the clay mineral kaolin which is a common constituent of estuarine waters and protected bays.

The type and concentration of the medium, initial and final colorimetric readings, elapsed time, and the number of test animals per species are summarized in Table 1. Initial colorimetric readings of test samples have been corrected to the initial colorimetric readings of the control sample. Total dry weight of tissues scraped from the shells and the average length of the test animals are also included in Table 1.

## RESULTS

**Experiment 1:** At the finish of the experiment samples from all test beakers had less turbidity than the control sample. Beakers with *Tellina buttoni*, *T. salmonea*, and *Transennella tantilla* had a net increase in percent transmission of light, or clarity, of 27.6%, 4.5%, and 21.0% respectively.

**Experiment 2:** Results of the experiment showed that samples from test beakers with the tellinids were less turbid than the control sample, while the sample from *Transennella tantilla* was slightly more turbid than the control. *Tellina buttoni* and *T. salmonea* had a net increase in percent transmission of light, or clarity, of 14.0% and 8.0% respectively, and *Transennella tantilla* had a net decrease of 2.5%.

**Experiment 3:** Final colorimetric readings of test samples showed little or no increase in clarity over the control. Values among the test animals were very close with *Tellina buttoni* 0.0%, *T. salmonea* 3.0%, and *Transennella tantilla* 5.0%.

**Experiment 4:** At the termination of the experiment samples from test beakers with *Tellina buttoni* and *Transennella tantilla* were less turbid than the control sample, while the sample with *Tellina salmonea* was definitely more turbid than the control. *Tellina buttoni* and *Transennella tantilla* had a net increase in clarity of 9.0% and 9.5% respectively, whereas *Tellina salmonea* had a net loss of 10.1%. Upon dissection it was found that in general the digestive tracts of a few *Tellina salmonea* were full of particles, but the majority contained very few ink particles. All specimens of *Tellina buttoni* had more ink particles in the mantle cavity and alimentary tract than *T. salmonea* and the small venerid *Transennella tantilla*. About one-third of the *Transennella tantilla* showed some particles in their intestines. The latter species also produced clumps of curlicue- and figure-8-like pseudofeces.

**Experiment 5:** Final readings in this experiment had all the test samples with less turbidity than the control. *Tellina buttoni*, *T. salmonea*, and *Transennella tantilla* had a

net increase in clarity of 7.3%, 6.3%, and 6.8% respectively. Values among test animals were very close. Upon dissection, *Tellina salmonea* contained some carmine particles. Red, sausage-shaped pellets occurred throughout the intestine. Among these specimens there was very little siphonal activity following the experiment. Carmine particles occurred in greater amounts within *Tellina buttoni* than in *T. salmonea*. Sausage-shaped strings of carmine pellets were present in the intestine of *T. buttoni* as well. Three-fourths of the *Transennella tantilla* contained scarcely a trace of carmine, while in the other specimens the intestine was full of carmine.

**Experiment 6:** Samples from test beakers had only a marginal gain of clarity over the control sample. Indeed, the sample with *Tellina salmonea* was slightly more turbid than the control. Values among the test samples were close as *Tellina buttoni*, *T. salmonea*, and *Transennella tantilla* had differences from the control of 0.5%, —3.5%, and 5.5% respectively. *Tellina salmonea* contained only a trace of kaolinite and very few feces. Shell movement was not observed during or after the experiment. *Tellina buttoni* formed sausage-shaped and round pellets as well as string-like masses of pseudofeces. These clams moved horizontally and attempted to burrow during the experiment. *Transennella tantilla* formed masses of milky-white pseudofeces and contained some sausage-shaped pellets in the intestine.

**Experiment 7:** This was the only experiment in which *Mysella tumida* was used. Final reading showed that the test sample was less turbid than the control. Test sample had a net increase of 17% over the control.

## DISCUSSION

Before results of the filtering experiments can be discussed an aspect of the study which was not treated should be mentioned. In order to compare the filtering rates of the tellinids, *Transennella tantilla*, and *Mysella tumida* it has been tacitly assumed that their ctenidial structure is comparable. Although the test species fit into the general category of eulamellibranchs, important modifications exist which certainly could influence filtering and feeding.

For example, *Transennella tantilla* is a venerid. Venerids, which usually feed as suspension feeders, have ctenidia with both inner and outer demibranchs and their palps are relatively small compared to the size of the gills. With *Transennella tantilla* LARSON (1966) figured tissue connections between gill filaments which are characteristic of eulamellibranchs. From her figures it can be seen that the palps are considerably smaller than the ctenidia.

Table 1

Filtering Rate of Pelecypods as Determined using Sea Water Concentrations of Milk, Carmine, India Ink, and Kaolinite. Results Expressed in the Relative Percent of Light Transmitted through the Suspensions.

	<i>Tellina buttoni</i>	<i>Tellina salmonea</i>	<i>Transennella tantilla</i>	<i>Mysella tumida</i>	Control	hours Elapsed Time min.
1.						
Initial	—	—	—		24.5%	00:00
Final	59.1%	36.0%	52.5%		31.5%	29:00
Number of Specimens	10	10	10			
Concentration	0.8 ml milk/250 ml sea water					
2.						
Initial	—	—	—		28.0%	00:00
Final	51.0%	45.0%	34.5%		37.0%	29:15
Number of Specimens	10	10	30			
Total Dry Weight mg	0.1065	0.1014	0.0122			
Concentration	0.8 ml milk/250 ml sea water					
3.						
Initial	—	—	—		27.0%	00:00
Final	42.0%	45.0%	47.0%		42.0%	28:45
Number of Specimens	20	20	20			
Total Dry Weight mg	0.0301	0.0279	0.0116			
Concentration	0.8 ml milk/250 ml sea water					
4.						
Initial	—	—	—		12.0%	00:00
Final	94.5%	75.4%	95.0%		85.5%	22:15
Number of Specimens	11	10	10			
Total Dry Weight mg	0.0800	0.0739	0.0975			
Average length cm	1.10	0.87	0.51			
Concentration	1 ml ink/1000 ml sea water					
5.						
Initial	—	—	—		0.0%	00:00
Final	28.5%	27.5%	28.0%		21.2%	24:30
Number of Specimens	10	10	25			
Total Dry Weight mg	0.1267	0.0786	0.0741			
Average length cm	1.04	0.87	0.50			
Concentration	1 g carmine/1000 ml sea water					
6.						
Initial	—	—	—		41.0%	00:00
Final	87.0%	83.0%	92.0%		86.5%	07:00
Number of Specimens	10	10	21			
Total Dry Weight mg	0.0590	0.0601	0.1156			
Average length cm	1.20	0.83	0.48			
Concentration	1 g kaolinite /1000 ml sea water					
7.						
Initial				—	10.0%	00:00
Final				52.0%		
Number of Specimens				20		
Total Dry Weight mg				0.0884		
Average length cm				0.28		
Concentration	0.5 ml milk/50 ml sea water					

According to MORTON (1958) the genus *Mysella* belongs in the superfamily Erycinacea and many members feed as suspension feeders. In this group of bivalves the outer demibranch may be reduced or lost. YONGE (1949) has characterized the Tellinacea as deposit feeders. However, the mode of feeding of *Tellina buttoni* and *T. salmonea* does not entirely support this view. In some members of the Tellinacea the gill surface is much reduced in comparison with the labial palps which tend to approach the gills in size. As a result much of the sorting of particles which is performed by gills in suspension feeders is carried out by the labial palps in tellinids.

It would be expected with such basic differences in ctenidia and feeding behavior that the filtering rates would vary from one group to the next. Until the functional morphology of *Tellina salmonea*, *T. buttoni*, *Transennella tantilla*, and *Mysella tumida* is known and their mode of feeding has been observed, any conclusions drawn from the filtering experiments must be considered tentative. Reference to other species used in filtering experiments is necessary to outline the general features of the problem and to obtain independent evidence for one's work. Still, in light of structural modifications and different feeding behavior it should be emphasized that results of other studies should be applied cautiously, unless similar ctenidial and feeding types are compared.

In general the test animals cleared the milk-sea water colloids faster than coarse suspensions, and as would be expected, they had less difficulty clearing the milk than the particulate material. A relative estimate of filtering ability can be determined by ranking the pelecypods one, two and three in order of their final degree of clarity for each experiment. *Tellina salmonea* finished last considerably lower than either *Tellina buttoni* or *Transennella tantilla*. The latter two species both finished with 3 firsts, 2 seconds, and 1 third.

Mode of feeding might help to explain the different filtering rates of the pelecypods. Members of the Tellinacea have been considered deposit feeders by YONGE. Between *Tellina buttoni* and *T. salmonea* rates of filtering and amount of material ingested were so different that a similar feeding habit would seem unlikely. Further observations should confirm or negate the suggestion that these tellinids are not restricted to deposit feeding, but may exhibit a dual feeding habit.

Dissections indicated that *Tellina buttoni* ingested more carmine, kaolinite, and ink particles than either *Tellina salmonea* or *Transennella tantilla*. *Tellina buttoni* also produced more pseudofeces than the other species. Although this tellinid had some difficulty ingesting particulate matter under laboratory conditions, its ability to filter the suspensions indicated a greater tolerance to turbid condi-

tions than *Tellina salmonea*. This might be a factor to explain its distribution and abundance in a range of sediment types wider than that of *T. salmonea*.

In view of the low filtering rates of *Tellina salmonea* it is understandable that less material was inhaled and thereby less opportunity offered for stuffing the palps and clogging the gills to occur. However, in contrast to *T. buttoni*, when *T. salmonea* ingested material it was able to process the particles through the alimentary tract as was evidenced by the sausage-shaped pellets in its intestine. Both feces and pseudofeces were produced. The apparent inability of *T. salmonea* to clear an artificial medium may be an indication of its mode of feeding and sensitivity to feed in turbid water and may help to explain its common distribution and abundance in clean, coarse sediments.

On the other hand, the small venerid *Transennella tantilla* combined the highest filtering rates with the least apparent difficulty of filtering the suspensions. Small tentacles surround the apertural margin of the siphons of *T. tantilla*. Such an arrangement suggests that the venerid probably feeds as a suspension feeder. The widespread occurrence of *T. tantilla* in various sediment types (MAURER, 1966) may be influenced by its ability to tolerate a certain degree of turbidity. This in turn may be controlled by its feeding apparatus. LIM (1966), who worked on a species of *Anadara* which lives in mud, discussed ciliary adaptations within pelecypods as related to environment or sediment type. He asserted that a large sorting area on the gills, well developed labial palps, more mucous secretion and ciliation of exposed parts presumably allowed the bivalve to cope with an environment of much silt and suspended particles in the surrounding water. Similar information on ciliary adaptations in *T. tantilla* would be most useful, but it should be remembered that the venerid is a lamellibranch and the arcid is a filibranch. Thus their response to the same turbidity might differ.

Insertion of *Mysella tumida* into the experiments indicated that this small species can be used in filtering experiments. BALLENTINE & MORTON (1956) have performed filtering experiments with *Lasaea rubra* MONTAGU, 1904, a closely related genus which is similar in size to *M. tumida*.

Further research with different concentrations of the same material, comparable sized species, greater control over water volume intake and oxygen, together with detailed knowledge of the functional morphology of the mollusks would improve the experimental design. LOOSANOFF (1962) commented on the radically different results obtained when mollusks are placed in small or large quantities of water during filtering experiments. He stated that a large mussel might rapidly clear a liter of water,



whereas a mussel placed in a large quantity of water might become exhausted long before the turbidity was significantly lowered. The volume of water and the number of pelecypods per beaker used in the present experiments seem to be commensurate with the small size of the bivalves. It should be mentioned that exclusive of kaolinite the media (milk, india ink, carmine) are not normal constituents of the marine environment, and filtering rates measured may not reflect performances in the natural state.

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# The Bursidae, Cymatiidae and Colubrariidae of Fiji

(Mollusca : Gastropoda)

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

(Plates 42 to 46; 14 Text figures)

THIS ACCOUNT COVERING the families Bursidae, Cymatiidae and Colubrariidae is the sixth faunal monograph dealing with Fiji mollusca. Only those species collected by resident collectors and the author have been taken into consideration.

Species of all three families have a wide distribution, living in warm waters of all major oceans. Further records of species are to be expected, especially for those of the Colubrariidae which at present are represented by only two species from Fiji.

For notes on the geography of the Fiji Islands and other pertinent data see CERNOHORSKY (1964).

## The Animal, Habitat and Variation

The foot is comparatively small, round and short, but solid and powerful in the Bursidae. Tentacles are moderately short, eyes are small and situated on the outside of the thickened base of the tentacles. Siphon is short, proboscis slender and moderately long. The animals of Cymatiidae are rather similar, but generally more colorful. Animals are fairly agile and move swiftly. An operculum is present in species of all three families, a hairy periostracum in the Cymatiidae.

Sexes are separate. The radula is taenioglossate, with seven teeth per row, and similar to the Cassidae. The Bursidae appear to have evolved from a tonnaceid ancestor during Upper Cretaceous or Paleocene times; the Cymatiidae and Colubrariidae are of a somewhat more recent origin.

Species of the three families are primarily reef dwellers, although some species of Cymatidae are found on sandy, broken coral substrate. They inhabit shallow water of the intertidal zone but also live in deeper water. Muddy sand localities appear to be their preferred habitat.

Species of Bursidae, Cymatidae and Colubrariidae appear to be less variable than other molluscan groups,

although they display a limited range of variation in sculpture and colour. The number of denticles on the labial lip would appear to be almost of the same diagnostic value as the labial teeth in Cypraeidae; the columellar plicae, however, display a greater range. Ecological variation is minimal, and far less pronounced than is the case in Cypraeidae and Conidae.

## The Genera

Species of these three families were combined under the genus *Murex* by LINNAEUS (1758) and GMELIN (1791). RÖDING (1798), however, was more discriminating and distributed the species among his new genera *Bursa*, *Cahestana*, *Cymatium*, *Distorsio* and *Tritonium* (non MÜLLER, 1776). During the 19th century many new genera were established, and the genera *Triton* MONTFORT, 1810 (non LINNAEUS, 1758) and *Ranella* LAMARCK, 1816, were widely used for the reception of the "Triton" species. By the time DALL (1904) and BAYER (1932, 1933) wrote their respective revisions of the Bursidae and Cymatiidae, about 70 generic names had been established for the two families which contain only a limited number of species; the majority of genera, in the light of present day evidence, are objective or subjective synonyms.

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#### BURSIDAE

##### *Bursa* RÖDING, 1798

*Bursa* RÖDING, 1798, Mus. Bolten., p. 128 - Type species by SD (JOUSSEAUME, 1881) *Bursa monitata* RÖDING, 1798 = *Bursa bufonia* (GMELIN, 1791).

**Characteristics:** Shell ovate, ventricose or flatly compressed at times, whorls convex and angulate, varices continuous or discontinuous, one or two at every whorl; shells with a coarse sculpture of spiral and axial cords and prominent knobs between varices. Labrum and columella calloused and dentate or plicate, anal canal prominent and occasionally with produced appendages; siphonal canal short, sometimes recurved. Periostracum almost obsolete or absent.

Operculum brown, orange-brown or yellowish-brown, thick or moderately thin, triangular, with long side rounded or regularly ovate and narrowing anteriorly, sometimes angulate. Nucleus either a: sub-lateral to the left, at centre of margin or slightly below; b: terminal or slightly offset to the right; or c: terminal but well away from margin or slightly offset to the right.

**Animal:** Foot short but powerful, tentacles moderately short and slightly recurved, generally cross-banded, eyes moderately small and situated on outer edges of thickened base of tentacles, siphon short, proboscis slender and moderately long.

**Radula:** Rhachidian trapezoidal in outline, with one long central cusp and a few small side-cusps, two prominent curved cusps situated on the interior margin of the plate; this last feature is absent in all genera of the Cymatiidae. Laterals with two to four cusps on the cutting edge, inner marginals with one cusp or without, outer marginals without accessory cusps.

**Egg-Mass:** Egg capsules encased in a gelatinous matrix and thus differ from the Cymatiidae which deposit capsules directly onto the substrate without a protective jelly-mass covering.

**Discussion:** The familial position of *Bursa* RÖDING has had an eventful history, as the genus has been placed in

the Tritoniidae (19th century authors), Bursidae (KURODA & HABE, 1952), Ranellidae (HABE, 1961), and Cymatiidae (GARRARD, 1961). Bursid species have, more often than not, been associated with the genus *Ranella* LAMARCK, 1816, and DALL (1904) and THIELE (1929) list *Murex bufonius* GMELIN, 1791, as the type species of *Ranella*. DELL & DANCE (1963) reviewed the taxonomy of the genus *Ranella* and correctly concluded that *Ranella gigantea* LAMARCK, 1816 (= *Murex olearium* LINNAEUS, 1758) is the type species of *Ranella* LAMARCK. LAMARCK's inclusion and delineation of nine nominal species in the genus *Ranella* (1816, pls. 412-414) precludes a type designation by monotypy (*vide* DELL & DANCE, 1963) or by subsequent monotypy (*vide* DALL, 1904, and HEPPELL, 1964), but rather by subsequent designation by CHILDREN (1823).

The familial separation of *Bursa* RÖDING from the family Cymatiidae is most appropriate in view of the type of spawn of *Bursa*. The egg mass is that of a more primitive mesogastropod, and would suggest a retarded stage of development of the Bursidae in comparison with some genera of the more advanced Cymatiidae. According to ANDERSON (1960) and the Hawaiian Shell News (1961, 1966) certain species of the genera *Mayena* IREDALE, 1917, *Cymatilesta* IREDALE, 1936 (= *Cabestana* RÖDING, 1798) and *Charonia* GISTEL, 1848, deposit egg-capsules directly onto the substrate without the egg cluster being encased in a solid gelatinous matrix (see under *Bursa granularis* RÖDING).

##### 1. *Bursa bubo* (LINNAEUS, 1758)

(Plate 42, Figure 1)

1758. *Murex rana bubo* β LINNAEUS, Syst. Nat., ed. 10, p. 748, no. 452

1798. *Tritonium bufo* RÖDING, Mus. Bolten., p. 128, no. 1647

1822. *Triton nodiferum* LAMARCK, Anim. sans Vert., 7: 179

1914. *Bursa* (*Tutusfa*) *rubeta* var. *gigantea* E. A. SMITH, Journ. Conch. 14: 230

**Shell:** Shell large and heavy, inflated; creamy-white or yellowish-brown, sparsely flecked with irregular dark brown patches or spiral rows of spots. Whorls convex, angulate, numbering 8-9 apart from protoconch; varices number two at every whorl, body whorl sculptured with prominent spiral cords and intermediate nodulose spiral lirae, and 6-8 prominent knobs are situated between varices on body whorl. Aperture wide, outer lip flaring, and with 20-25 small brown denticles at edge of lip, and 10-12 white denticles further towards the interior of the aperture; columella calloused, and with 28-34 plicae which extend to the parietal wall. Anal canal

short, siphonal canal calloused and only moderately produced, deep interior of aperture white or light yellow.

**Size:** 128 to 258 mm.

**Habitat:** Under coral rocks, on sand and coral substrate, in shallow and deeper water.

Uncommon.

**Distribution:** South and Southwest Viti Levu, Yasawa Islands. – From East Africa through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

**Discussion:** In Fiji specimens examined, the colour of the aperture and columella varied from white to light orange.

## 2. *Bursa bufonia* (GMELIN, 1791)

(Plate 42, Figure 4)

1758. *Murex rana* LINNAEUS (pars), Syst. Nat., ed. 10, p. 748, no. 451

1791. *Murex bufonius* GMELIN, Syst. Nat., ed. 13, p. 3534 (non *Bursa bufonia* RÖDING, 1798)

1798. *Bursa mammata* RÖDING, Mus. Bolten., p. 128

1798. *Bursa monitata* RÖDING, Mus. Bolten., p. 129

1807. *Gyrineum bufonium* LINK, Besch. Nat.-Samml. Univ. Rostock, p. 123

1964. *Bursa leo* SHIKAMA, Sel. shells world, 2: 115, pl. 62, fig. 10 & text fig. 194 - upper figure (immature specimen)

**Shell:** Shell moderate in size, ponderous and heavy; creamy-white in colour, ornamented with brown lines and blotches, but generally heavily encrusted with lime and foraminifera. Whorls number 5, apart from protoconch which was missing in specimens examined; there are 2 varices at each whorl, and they are generally in vertical alignment; 2-3 heavy knobs are situated between varices, and body whorl is sculptured with 3-4 coarse spiral ridges and smaller obsolete nodulose cords. Aperture white, outer edge of labial lip cream in colour and often with a greenish tint; outer lip with 10-11 prominent white denticles. Columella calloused, outer edge cream-coloured, columellar wall white, sculptured with 28-32 white and close-set plicae, and a blunt larger denticle near the anal canal. Siphonal canal short, anal canal moderately produced, interior of aperture porcelain white.

**Size:** 50 to 70 mm.

**Habitat:** Under coral rocks, on solid reef substrate, in shallow and deeper water.

Moderately rare.

**Distribution:** West Viti Levu. – From Mauritius through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

**Discussion:** The close-set, numerous and almost regular columellar plicae are an outstanding feature in this species.

## 3. *Bursa cruentata* (SOWERBY, 1835)

(Plate 43, Figure 7)

1835. *Ranella cruentata* SOWERBY, Conch. Illust., *Ranella*, pl. 85, figs. 5, 5\*

1841. *Ranella cruentata*, SOWERBY, Proc. Zool. Soc. London, p. 51

**Shell:** Shell moderately small and solid; dirty-white to creamy-yellow in colour, occasionally ornamented with a few isolated lilac spots on nodules. Whorls number from 5-6, each whorl with 2 varices, protoconch missing in specimens examined. The shell is heavily sculptured with nodulose spiral cords of varying size, and 3-4 large double knobs between varices on body whorl; there are 4 such knobs on the penultimate and earlier whorls. Aperture white in colour, outer lip slightly expanded, and sculptured with 9-10 white denticles and 3 small expanding digits; anal canal short. Columella with 5-12 white denticles, columellar wall with cords which extend from body whorl inside aperture; the columella is ornamented with 4-5 close-set, short and dark chocolate-brown bars. Parietal wall with 1-2 small denticles, siphonal canal moderately short and fairly open.

**Size:** 22 to 40 mm.

**Habitat:** Under coral rocks in shallow water.

Moderately rare.

**Distribution:** South and West Viti Levu. – From South Africa through the tropical Indo-Pacific to Polynesia, the Hawaiian and Clipperton Islands.

## 4. *Bursa granularis* (RÖDING, 1798)

(Plate 42, Figure 6; Plate 43, Figure 11; Text figures 1-3)

1798. *Tritonium jabick* RÖDING, Mus. Bolten., p. 127

1798. *Tritonium granulare* RÖDING, Mus. Bolten., p. 127

1816. *Ranella granifera* LAMARCK, Tabl. Encyc. Méth., p. 4, pl. 414, fig. 4

1822. *Ranella semigranosa* LAMARCK, Anim. sans Vert., 7: 153

1832. *Ranella affinis* BRODERIP, Proc. Zool. Soc. London, p. 179

1844. *Ranella livida* REEVE, Conch. Icon., pl. 6, sp. 28

1880. *Ranella fijiensis* WATSON, Journ. Linn. Soc. London 15: 270

1886. *Ranella fijiensis*, WATSON, Voy. H. M. S. Challenger, pt. 42, p. 397, pl. 34, fig. 7

1932. *Bursa alfredensis* TURTON, Mar. shells Pt. Alfred, p. 107, pl. 24, no. 781

**Shell:** Shell moderate in size, laterally compressed; variable in colouring, but generally light orange-brown or dark reddish-brown, with occasional light-coloured spiral lines and flecks on varices. Whorls convex, numbering 6 apart from protoconch of 3 orange-brown smooth nuclear whorls; two varices at each whorl, and these are generally in vertical alignment. Body whorl sculptured with 11-16 spiral rows of nodules, some larger than others, penulti-

mate whorl with 5-6 rows of nodules; interstices of nodules finely spirally striate, axial striae very faint. Aperture white or creamy-white, outer lip with 14-16 white denticles; columella and columellar wall with 17 to 23

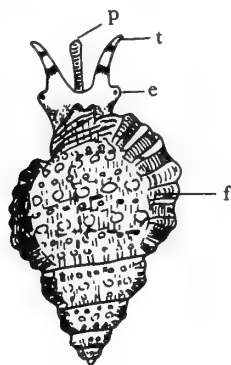


Figure 1

*Bursa granularis* (RÖDING). Fiji Islands.

Animal and Shell

p - Proboscis    t - Tentacles    e - Eyes    f - Foot

denticles which extend as plicae into the aperture; parietal wall with 1-2 denticles. Siphonal and anal canals short but fairly deep.

**Animal:** Foot creamy-white, siphon white and longitudinally lined with dark grey; tentacles moderately short in comparison with shell-length, banded with 2 blackish zones consisting of short and close-set longitudinal lines; eyes moderately small, blackish-grey in colour.

**Radula:** Radular ribbon translucent creamy-white, measuring 5.1 mm in length and 0.6 mm in width in an animal with a shell 42 mm in length; ribbon has 52 fully formed rows of teeth (+ 7 nascentes), and the first rows of teeth are worn. Rhachidian roughly trapezoidal in outline,

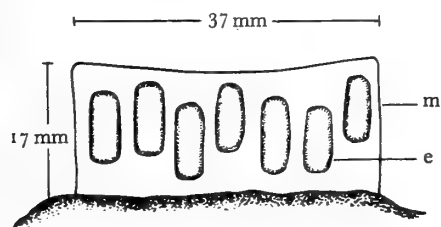


Figure 2

*Bursa granularis* (RÖDING). Fiji Islands.

Lateral View of Egg Mass

m - Gelatinous Matrix    e - Egg Capsules

broader than long, with a moderately long and massive central cusp; prominent inward pointing cusps are situated on the interior margins of the central plate; the central cusp is flanked by three small denticles on either side, but the number of side-denticles is variable, generally not exceeding four on either side. Lateral is massive and beak-shaped, and equipped with 2-3 accessory cusps on the cutting edge; the inner and outer marginals are sickle-shaped and carry no denticles.



Figure 3

*Bursa granularis* (RÖDING). Fiji Islands.

a. Half Row of Radular Teeth

b. Operculum

**Egg-Mass:** The egg-mass consists of a solid translucent gelatinous matrix, oval in outline, measuring 37 mm in length, 30 mm in width and 17 mm in height. The jelly-mass is fairly regular and smooth, with the top prominently concave. Egg-capsules are flatly cylindrical, bright yellow in colour, feathery, and measure 8 mm by 9 mm in height; the 28 capsules counted were well-spaced, suspended on edge and completely embedded in the matrix, which was firmly attached to the underside of a coral rock.

**Size:** 35 to 53 mm.

**Habitat:** Under coral rock on sand and reef substrate, in shallow and deeper water; preferred habitat is muddy-sand environment.

**Common.**

**Distribution:** Throughout the Fiji Islands. – From East Africa through the tropical Indo-Pacific to Polynesia, the Hawaiian and Clipperton Islands, Southeast Florida and the West Indies.

**Discussion:** IREDALE in 1931 established the genus *Dulcerana* specifically for the species *Bursa granifera* (LAMARCK), which he synonymized with *Bursa granularis* (RÖDING) and *B. jabick* (RÖDING). IREDALE's new genus name, however, is a *nomen nudum*.

#### 5. *Bursa nobilis* (REEVE, 1844)

(Plate 42, Figure 5; Text figure 4)

1844. *Ranella nobilis* REEVE, Conch. Icon., *Ranella*, pl. 4, sp. 16  
1931. *Gyrineum pacator* IREDALE, Rec. Austral. Mus., 18: 214, pl. 23, fig. 3

**Shell:** Shell moderate in size, solid and moderately heavy; creamy-white to fawn in colour, sparsely ornamented with small rusty-brown blotches and spots or spiral lines.

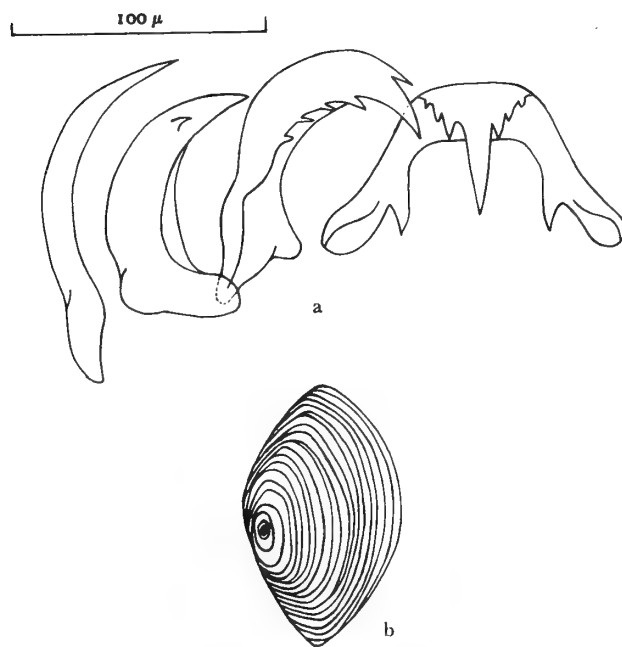


Figure 4

*Bursa nobilis* (REEVE). Fiji Isands.

a. Half Row of Radular Teeth

b. Operculum

Whorls convex, numbering from 4 - 6 apart from protoconch of 3 smooth nuclear whorls; varices number 2 at every whorl and are in vertical alignment; prominent

flat and slightly triangular knobs are positioned between varices on the dorsal side of the body whorl, while from the ventral view 2 - 4 knobs are visible between varices. Sculpture consists of 15 - 16 nodulose spiral ridges on the body whorl and 5 - 7 ridges on the penultimate whorl; interstices are finely axially striate and ornamented with smaller satellite cords. Outer lip yellow or orange at edge, sculptured with 12 - 16 white denticles which are often elongate; columella heavily calloused, yellow or orange at outer edge, sculptured with 13 - 21 white denticles which become plicae on the columellar wall; parietal wall with 1 or 2 prominent denticles and sometimes 1 or 2 smaller denticles. Siphonal canal short, anal canal moderately produced, interior of aperture white.

**Radula:** Radular ribbon translucent white, 3.1 mm long and 0.3 mm wide in an animal with a shell 42.0 mm in length; fully formed rows number 58 (+ 5 nascentes), and wear on teeth was visible in the first 10 anterior rows. Rhachidian is of the *Bursa* pattern, with 1 prominent central cusp which is flanked by 3 smaller side-cusps; single prominent cusps emanate from the interior edge of the plate. Laterals with 4 small cusps on each side of the cutting edge, the first cusp being the largest; inner marginal with 1 cusp, outer marginal sickle-shaped and without cusps.

**Size:** 24 to 57 mm.

**Habitat:** Under coral rocks on sand and reef substrate, in shallow and deeper water.

Uncommon.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands to Polynesia.

**Discussion:** In all specimens examined, one of the knobs on the dorsal side of the body whorl was appreciably larger than the others, and prominently compressed.

#### 6. *Bursa rhodostoma* (SOWERBY, 1835)

(Plate 43, Figure 9; Text figure 5)

1835. *Ranella rhodostoma* SOWERBY, Conch. Illust., *Ranella*, pl. 88, fig. 10

**Shell:** Shell small and solid; creamy-white or light yellow in colour, generally well encrusted with lime. Whorls angulate, numbering 5 apart from protoconch which is generally missing; varices are in vertical alignment and number 2 at every whorl; 2 - 3 prominent fused knobs are situated between varices. The body whorl is sculptured with 3 coarse spiral ridges and 2 - 3 additional spiral rows of nodules; interstices with very fine spiral and axial striae. Aperture wine-coloured, outer lip somewhat expanded, flattened and foliated, ornamented with 8 - 9

small white denticles; columella calloused, ornamented with scattered white denticles and nodules on a wine-coloured background. Siphonal canal very short.

**Size:** 10 to 25 mm.

**Habitat:** On broken coral substrate, from 0 - 15 fathoms.

Moderately rare.

**Distribution:** South and West Viti Levu. - From the Philippine Islands through the tropical Pacific to the Hawaiian Islands.



Figure 5

Operculum of *Bursa rhodostoma* (SOWERBY). Fiji Islands.

**Discussion:** *Bursa venustula* (REEVE, 1844) is a similar species, but is generally slightly larger, the columella bears numerous elongated and irregular plicae, the labial lip is not flattened and expanded beyond the denticles as is the case in *B. rhodostoma*; the anal canal is generally longer than in *B. rhodostoma*. The species *B. venustula* appears to be confined to Polynesia and has been recorded from Baker Island, Canton Island and Christmas Island (Dr. H. Rehder, *in litt.*).

#### 7. *Bursa rosa* PERRY, 1811

(Plate 42, Figure 3; Text figure 6)

1811. *Bursa rosa* PERRY, Conchology, pl. 4, fig. 1

1844. *Ranella siphonata* REEVE, Conch. Icon., *Ranella*, pl. 7, sp. 38

1961. *Bursa mammata* RÖDING, HABE, Col. illust. shells Japan 2: 47, pl. 24, fig. 2 (non RÖDING, 1798)

1963. *Bursa (Bursa) mammata* RÖDING, SHIKAMA, Sel. shells world, 1: 64, pl. 49, fig. 4 (non RÖDING, 1798)

**Shell:** Shell moderate in size, solid and heavy; dirty-grey or creamy-yellow in colour, occasionally ornamented with small patches of purplish-brown on nodules and varices. Whorls number 5-6 apart from protoconch, sutures indistinct; there is one varix at every whorl, and siphonal appendages emanate from varices at the junction of columella and labrum. Whorls with 2-4 prominent knobs between varices on the ventral surface, and 2-3 knobs on the dorsal surface; ultimate knobs are connected with the outer lip and varix by 3-4 elevated and coarse spiral

ridges; prominent axial ridges descend onto nodules. Edge of outer lip and columella yellowish, outer lip with 8-10 whitish denticles which are generally arranged in pairs, and more or less confined to the edge of the lip. Columella

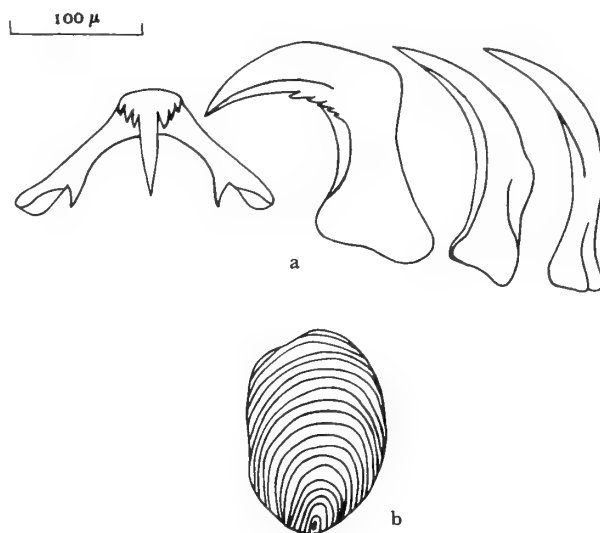


Figure 6

*Bursa rosa* PERRY. Fiji Islands.

a. Half Row of Radular Teeth

b. Operculum

wine-coloured, with 1-3 prominent whitish plicae posteriorly and 3-6 denticles anteriorly; remainder of columella with 9-16 rather obsolete plicae extending towards the purplish-brown or wine-coloured interior. Anterior canal short and truncated.

**Radula:** Radular ribbon translucent white, 5.7 mm in length and 0.48 mm in width in an animal with a shell 40.0 mm in length; fully formed rows number 69 (+ 6 nascentes) and the first 12 anterior rows show appreciable wear. Rhachidian of *Bursa* pattern, with a long and prominent central cusp which is flanked by 3 side-cusps; a prominent cusp is positioned on the interior edge of the plate. Lateral with 5 cusps on cutting edge, inner and outer marginals sickle-shaped and without cusps.

**Size:** 25 to 50 mm.

**Habitat:** Under coral rocks, on sand and coral substrate, in shallow and deeper water.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - From the Philippine Islands through the tropical Pacific to the Hawaiian Islands.

8. *Bursa* species

(Plate 42, Figure 2)

1963. *Bursa (Bursa) bufonia* (GMELIN), SHIKAMA, Sel. shells world, 1: 64, pl. 49, fig. 1 (non *Murex bufonius* GMELIN, 1791)

**Shell:** Shell moderate in size, solid and somewhat compressed; cream in colour, ornamented with large and small areas of white, yellow and purple, and occasional brown spiral zones. Whorls angulate, numbering 6 apart from protoconch; varices are vertically aligned and number 2 at every whorl, 2-3 prominent knobs are situated between varices. Sculpture consists of 5-6 coarse spiral cords which are more prominent near varices, and axial ridges tend to be obsolete in large specimens. Outer lip dark purple or purple-brown, ornamented with 9-10 cream-coloured denticles which persist as plicae for some distance towards the interior of aperture. Columella deep purple or chocolate-brown, sculptured with 20-21 whitish or creamy plicae which extend around pillar and towards the parietal wall; the latter bears a prominent plica and 2-3 small denticles. Siphonal canal short, anal canal produced and visible on 2-3 whorls; deep interior of aperture white.

**Size:** 40 to 73 mm.

**Habitat:** Under coral rocks on sand and coral substrate, generally in deeper water.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - Japan.

**Discussion:** This species has been generally united with *Bursa bufonia* (GMELIN) and appears to be nameless. DESHAYES (1843, p. 546) separated this distinct species but did not provide a name for it. Workers with a comprehensive library at their disposal could verify that the species is indeed nameless and provide it with a name.

## CYMATIIDAE

*Cymatium* RÖDING, 1798

*Cymatium* RÖDING, 1798, Mus. Bolten., p. 129 - Type species by SD (DALL, 1904) *Cymatium femorale* (LINNAEUS, 1758)

**Characters:** Shells moderately small to large, generally fairly solid, ovate and ventricose, whorls few, convex or angulate, varices prominent and discontinuous; whorls generally sculptured with spiral cords, axial ridges, nodules and knobs. Labial lip and columella calloused, denticulate or plicate, anal canal obsolete, siphonal canal moderately short or very long, slender or broad, recurved or twisted. Periostracum yellowish-brown to dark brown and with hair-like projections.

Operculum is variable, but generally orange-brown in colour and thick, slender or broadly ovate, sometimes triangular with the long side rounded, or narrowing posteriorly. Nucleus either a: terminal and at edge of margin or slightly offset to the right; or b: central and slightly offset towards terminal margin; or c: submarginal to the left and slightly below centre.

The animal is similar to that of *Bursa* RÖDING, but marked with colourful round, elliptical, trigonal or hexagonal spots.

The rhachidians of the radular ribbon are laterally excavated, convex or concave at the top, convex at base of plate, broader than they are long, and with a prominent long or short central cusp and 4-5 smaller cusps at either side. Laterals with 5-8 accessory cusps on cutting edge of large cusp, inner and outer marginals simple, and without cusps.

1. *Cymatium caudatum* (GMELIN, 1791)

(Plate 45, Figure 20; Text figure 7)

1791. *Murex caudatus* GMELIN, Syst. Nat., ed. 13, p. 3535 (non *Cymatium caudatum* RÖDING, 1798)

1822. *Triton canaliferum* LAMARCK, Anim. sans Vert., 7: 184

**Shell:** Shell moderate in size, solid and with a long anterior canal; white in colour, sparsely blotched on varices, nodules and body whorl with orange-brown. Whorls number 4 apart from protoconch of 4 glassy-brown nuclear whorls; one varix is positioned at every whorl. Body



Figure 7

Operculum of *Cymatium caudatum* (GMELIN). Fiji Islands.

## Explanation of Plate 42

Figure 1: *Bursa bubo* (LINNAEUS). Fiji. x 0.4

Figure 2: *Bursa* species. Fiji. x 1.0

Figure 3: *Bursa rosa* PERRY. Fiji. x 1.7

Figure 4: *Bursa bufonia* (GMELIN). Fiji. x 1.0

Figure 5: *Bursa nobilis* (REEVE). Fiji. x 1.3

Figure 6: *Bursa granularis* (RÖDING). Fiji. x 1.5



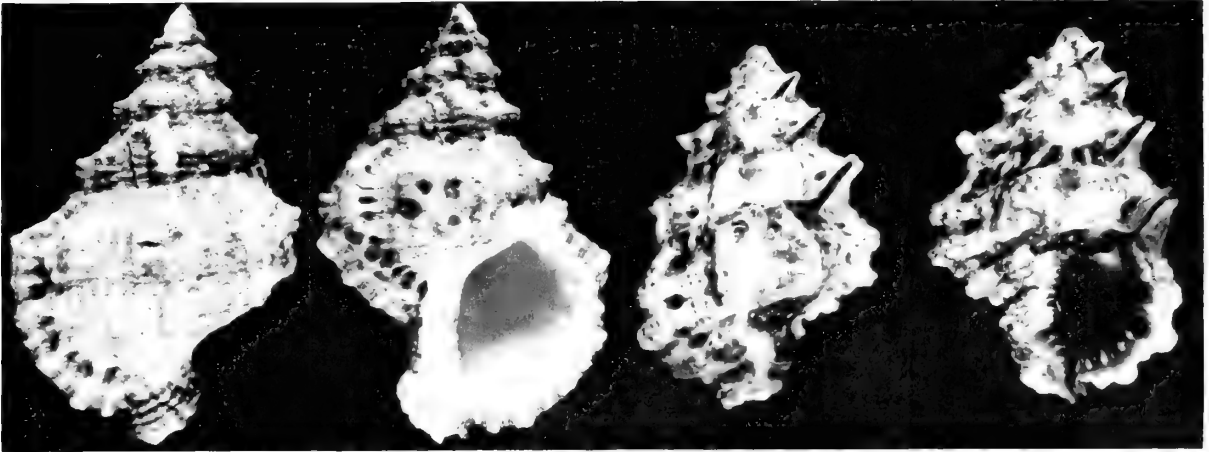


Figure 1

Figure 2

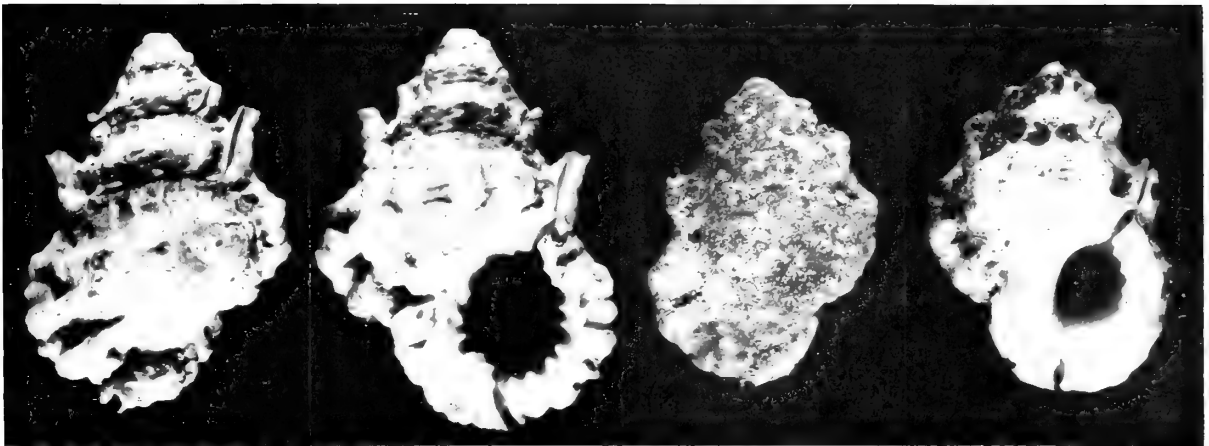


Figure 3

Figure 4

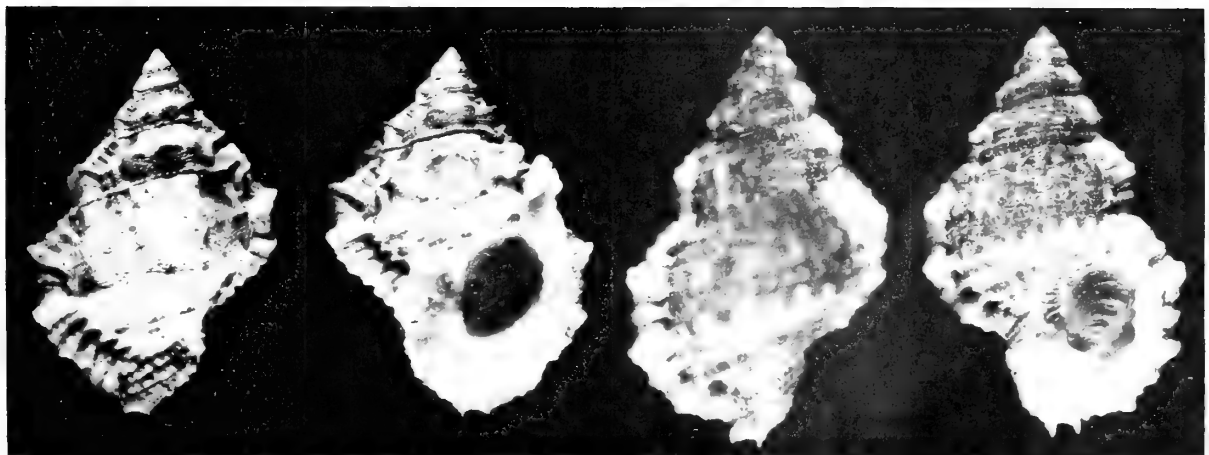


Figure 5

Figure 6



whorl with 4 - 6 prominent and angulate knobs between varices, and 11 - 17 prominent spiral cords and smaller intermediate cords; close-set axial ridges extend from suture to suture and override axial ribs and interstices. Aperture bright red, deep interior white; outer lip thickened, bright orange-red, ornamented with about 7 prominent denticles which extend a short way towards the interior of the aperture. Columella calloused, sculptured with 3 - 5 denticles, columellar wall smooth on outer edge but with 6 - 9 spiral plicae in interior, parietal wall with 3 - 4 strong plicae. Anal canal almost obsolete, siphonal canal long, slender and twisted; the twist in the siphonal canal can be either to the left or to the right.

**Size:** 40 to 66 mm.

**Habitat:** Dredged on sand and coral substrate, from 0 to 3 fathoms.

**Rare.**

**Distribution:** Throughout the Fiji Islands. - From Indonesia to Japan and the Fiji Islands.

## 2. *Cymatium gemmatum* (REEVE, 1844)

(Plate 44, Figure 17)

1844. *Triton gemmatum* REEVE, Conch. Icon., *Triton*, pl. 15, sp. 60

1849. *Triton mundum* GOULD, Proc. Bost. Soc. Nat. Hist. 6: 143

1936. *Septa blacketi* IREDALE, Rec. Austral. Mus., 19: 307, pl. 23, fig. 3

**Shell:** Shell small but fairly solid; creamy-white or yellow in colour, occasionally ornamented with light narrow bands and yellow flecks. Whorls angulate, numbering 6 apart from protoconch; there are 1 - 2 varices at every whorl, and 2 - 3 knobs positioned between varices on body whorl. Body whorl sculptured with 15 - 27 spiral ridges of varying size, which extend to the siphonal canal; spiral ridges are clathrate by 45 - 60 moderately prominent axial riblets which override spiral cords; penultimate whorl with 3 - 5 spiral ridges. Aperture white, outer lip with 10 - 15 prominent white denticles; columella white, with 13 - 14 white denticles which become plicae on the columellar wall. Parietal wall with one prominent white denticle. Siphonal canal only moderately produced, anal canal moderately deep, interior of aperture porcelain-white.

Periostracum light yellow, smooth, and only with short hairy projections on varices.

**Size:** 18 to 31 mm.

**Habitat:** Under coral boulders, on sand and coral substrate, in shallow and deeper water.

**Uncommon.**

**Distribution:** Throughout the Fiji Islands. - From Mauritius throughout the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

## 3. *Cymatium hepaticum* (RÖDING, 1798)

(Plate 44, Figure 14)

1798. *Tritonium hepaticum* RÖDING, Mus. Bolten., p. 126

1807. *Tritonium rubecula* LINK (pars), Besch. Nat.-Samml. Univ. Rostock, p. 122 (non *Murex rubecula* LINNAEUS, 1758)

**Shell:** This species resembles *Cymatium rubeculum* (LINNAEUS) very closely, but it is reddish-brown or reddish-tan in colour and ornamented with 6 - 8 blackish transverse bands in the interstices of spiral ridges, and small white patches appear on varices. The interstices of the labial denticles are coloured reddish-orange, whereas they are white in *C. rubeculum*. The interstices of the spiral ridges are sculptured with 2 - 4 fine spiral ridges; in all other characters the species approaches *C. rubeculum*.

**Size:** 30 to 51 mm.

**Habitat:** Under coral rocks, on sand and coral substrate, in shallow and deeper water.

Moderately rare.

**Distribution:** Throughout the Fiji Islands. - From the Philippine Islands to Polynesia.

## 4. *Cymatium labiosum* (WOOD, 1828)

(Plate 43, Figure 8)

1828. *Murex labiosus* WOOD, Ind. Test., Suppl., p. 15, pl. 5, fig. 18

1843. *Tritonium rutilum* MENKE, Mollusc. Nov. Holl. Spec., p. 25

**Shell:** Shell small and solid; dark rusty-brown in colour, ornamented with one or two obsolete spiral bands in the interstices of spiral ridges on the body whorl. Whorls angulate, numbering 4 - 5 apart from protoconch; there is one varix at every whorl, and 3 - 4 prominent knobs are situated between varices and are connected to sutures by strong axial cords. Body whorl sculptured with 4 - 6 main spiral cords, penultimate whorl with 2 cords; intermediate finely beaded spiral ridges are situated between main cords, interstices of ridges are axially grooved and spirally striate. Aperture white and oval, outer lip produced, ornamented with 6 prominent and blunt white denticles which extend partly towards the interior of the aperture; columellar wall smooth and white, parietal wall with one denticle; anal canal almost obsolete, siphonal canal moderately short.

**Size:** 28 to 34 mm.

**Habitat:** Unknown. Known from collection of dead specimens only.

**Rare.**

**Distribution:** South Viti Levu. – Indonesia, Japan, Philippines and Kermadec Islands.

5. *Cymatium muricinum* (RÖDING, 1798)

(Plate 44, Figure 18; Text figure 8)

1798. *Distorsio muricina* RÖDING, Mus. Bolten., p. 133

1807. *Tritonium nodulus* LINK, Besch. Nat.-Samml. Univ. Rostock, p. 122

1822. *Triton tuberosum* LAMARCK, Anim. sans Vert., 7: 185 (non *Tritonium tuberosum* RÖDING, 1798)

1849. *Triton pyriformis* CONRAD, Journ. Acad. Sci. Philad. 2(1): 211

**Shell:** Shell moderate in size, solid and fairly heavy; dirty white or light grey in colour, sometimes with lighter or darker areas on body whorl. Whorls angulate, numbering about 6 apart from protoconch; there are 2 varices at every whorl, and 3-5 prominent knobs are positioned between varices on the body whorl. Sculpture consists of 15-17 spiral ridges on the body whorl, of which about 7 are generally more prominent; penultimate whorl with 5 to 10 spiral ridges and obsolete axial striae. Outer lip calloused, creamy-white in colour, ornamented with 6-7 coarse white denticles which extend for a short distance into the aperture; columella heavily calloused, creamy-white, with 4-9 columellar plicae which become somewhat obsolete on the columellar wall; parietal wall with 1 or 2 denticles. Siphonal canal moderately slender and produced, recurved towards dorsum; interior of aperture purplish brown.

**Animal:** Foot creamy-yellow, ornamented with numerous light grey spots, edges of foot marked with larger trigonal and oblong rusty-brown spots. Siphon translucent white, edges adorned with brown round and oblong spots.

**Radula:** Radular ribbon translucent-white, 2.6 mm long and 0.19 mm wide in an animal with a shell 37.0 mm in length; fully formed rows number 65 (+ 8 nascentes), and some wear was discernible on the first half dozen rows of teeth. Rhachidians broader than long, concavely excavated at sides and base, and with a moderately long

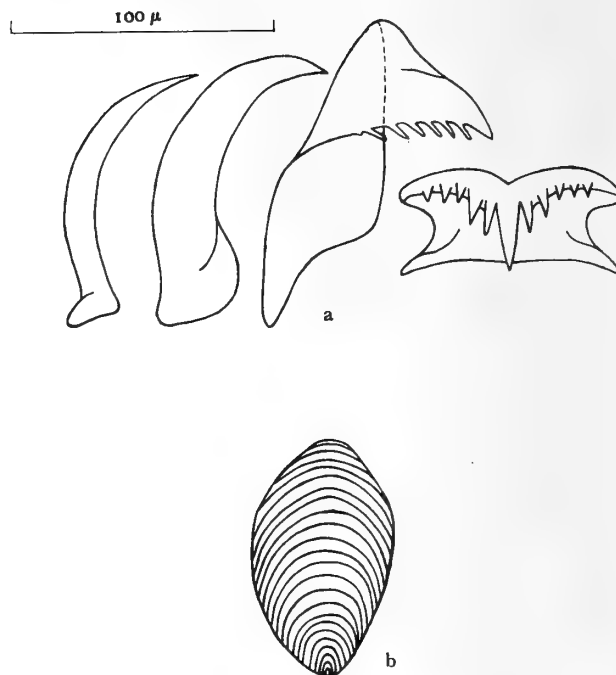


Figure 8

*Cymatium muricinum* (RÖDING). Fiji Islands.

a. Half Row of Radular Teeth

b. Operculum

central cusp which is flanked by 5 accessory cusps on either side. Laterals with a broad cutting cusp which bears 6-7 slender accessory cusps on the cutting edge; inner and outer marginals simple and without accessory cusps.

**Size:** 30 to 65 mm.

**Habitat:** Under coral rocks, on sand and coral substrate, often in muddy sand localities, in shallow water.

**Common.**

**Distribution:** Throughout the Fiji Islands. – From East Africa through the tropical Indo-Pacific to Polynesia, the Hawaiian Islands, Florida and the West Indies.

Explanation of Plate 43

Figure 7: *Bursa cruentata* (SOWERBY). Fiji. x 2.0

Figure 8: *Cymatium labiosum* (WOOD). Fiji. x 2.0

Figure 9: *Bursa rhodostoma* (SOWERBY). Fiji. x 3.0

Figure 10: *Cymatium pileare* (LINNAEUS). Fiji. x 1.0

Figure 12: *Cymatium nicobaricum* (RÖDING). Fiji. x 1.0

Figure 10 a: *Cymatium pileare* (LINNAEUS). – periostracum removed. Fiji. x 1.0

Figure 11: *Bursa granularis* (RÖDING). – sculptural variant. Fiji. x 1.4



Figure 7

Figure 8

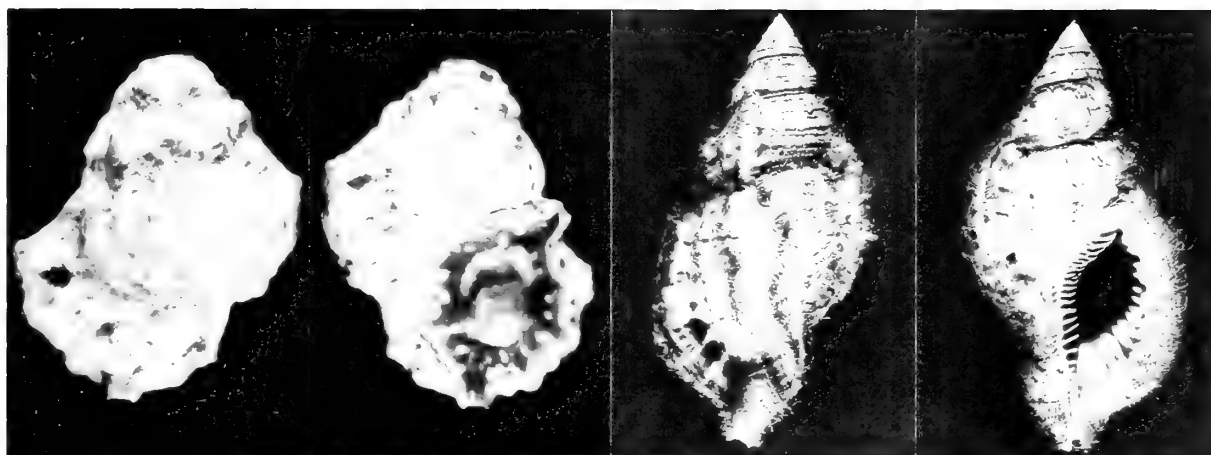


Figure 9

Figure 10

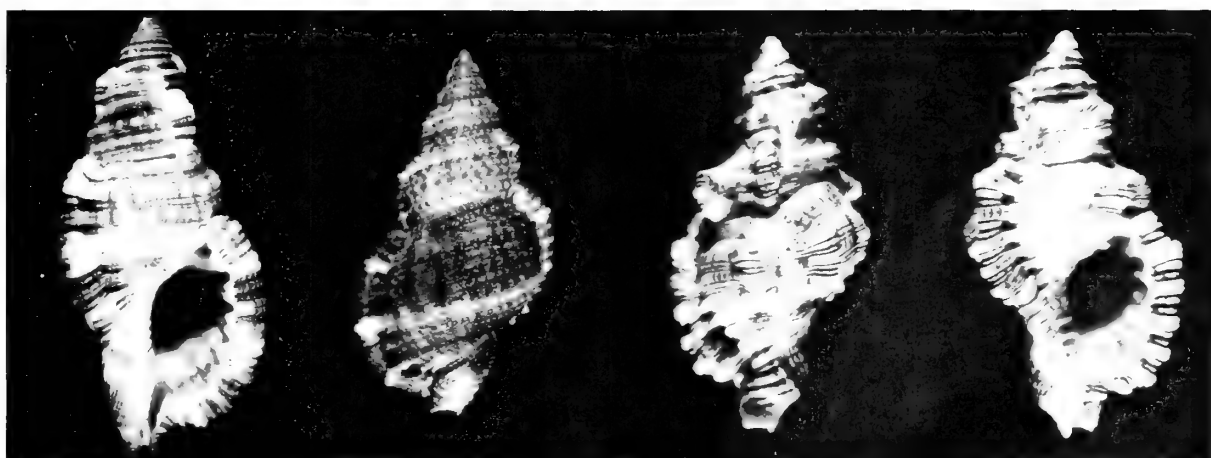


Figure 10 a

Figure 11

Figure 12



6. *Cymatium nicobaricum* (RÖDING, 1798)

(Plate 43; Figure 12; Text figure 9)

1798. *Tritonium nicobaricum* RÖDING, Mus. Bolten., p. 1261807. *Tritonium lotorium* LINK, Besch. Nat.-Samml. Univ. Rostock, p. 122 (non *Murex lotorium* LINNAEUS, 1758)

**Shell:** Shell moderate in size, fairly solid; creamy-white in colour, irregularly flecked and lined with rusty-brown. Whorls angulate, numbering 4 - 6 apart from protoconch of 4 light-brown glassy nuclear whorls; there are two varices at every whorl and 3 - 5 prominent knobs are positioned between varices. Sculpture consists of close-set flattish spiral ridges numbering from 20 - 32 on the body whorl and from 10 - 13 on the penultimate whorl; spiral ridges are of varying widths and are bisected by obsolete axial ridges forming weak nodules on spiral cords; these

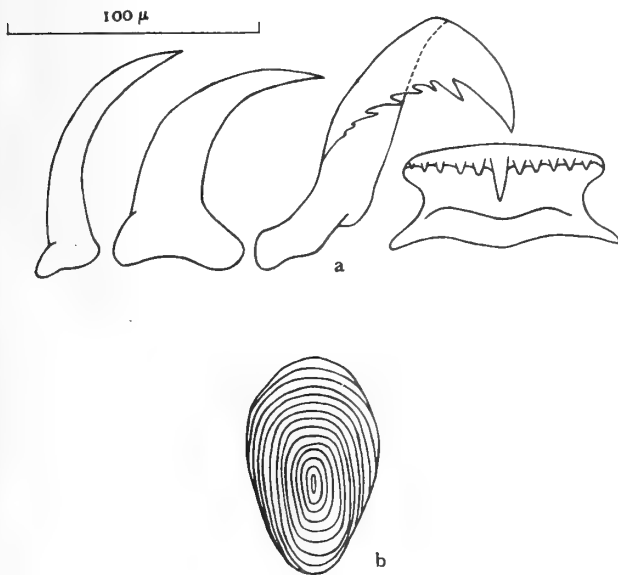


Figure 9

*Cymatium nicobaricum* (RÖDING). Fiji Islands.

a. Half Row of Radular Teeth

b. Operculum

nodules are occasionally spotted with brown. Aperture orange or reddish-orange, outer edge of labial lip white and ornamented with 7 - 14 white denticles; columella orange in colour, sculptured with 11 - 19 denticles which extend as plicae towards the parietal wall. Siphonal canal only moderately produced.

**Radula:** Radular ribbon translucent white, 3.2 mm long and 0.21 mm wide in an animal with a shell 44.0 mm in

length; fully formed rows number 101 (+ 7 nascentes) and some wear was discernible on anterior rows of teeth. Rhachidian broader than long, concavely excavated centrally, and with a moderate-sized central cusp which is flanked by 4 - 5 side cusps. Laterals with 5 - 7 denticles on cutting edge, marginals sickle-shaped and without accessory denticles.

**Size:** 24 to 77 mm.

**Habitat:** Under coral rocks, on reef substrate, in shallow water.

**Common.**

**Distribution:** Throughout the Fiji Islands. - From Mauritius through the tropical Indo-Pacific to Polynesia, the Hawaiian Islands, Florida and the West Indies.

7. *Cymatium pileare* (LINNAEUS, 1758)

(Plate 43, Figures 10, 10 a; Text figure 10)

1758. *Murex olearium* LINNAEUS (pars), Syst. Nat., ed. 10, p. 7481758. *Murex pileare* LINNAEUS, Syst. Nat., ed. 10, p. 7491844. *Triton aquatilis* REEVE, Conch. Icon., *Triton*, pl. 7, sp. 241844. *Triton vestitus* HINDS, Proc. Zool. Soc. London, pt. 12, : 211845. *Triton martinianum* D'ORBIGNY, Hist. pol. nat. Isl. Cuba, 5: 2491869. *Triton intermedius* PEASE, Amer. Journ. Conch., 5: 74 (juvenile)1878. *Triton veliei* CALKINS, Proc. Dav. Acad. Nat. Sci. 2: 235, pl. 2, figs. 1, 2

**Shell:** Shell moderately large and solid; creamy white or creamy-yellow in colour, irregularly ornamented with brown transverse bands and axial streaks. Whorls convex, numbering from 6 - 7 apart from protoconch of 4 creamy-white or light fawn glassy nuclear whorls; body whorl and penultimate whorl with 2 varices per whorl, 6 - 10 knobs between varices, and numerous beaded spiral cords and axial ridges. Aperture orange to reddish-orange, outer lip with 14 - 17 white denticles which are often arranged in pairs and extend as white plicae into the aperture; columella calloused, deep red or purplish-brown, ornamented with 22 - 30 white plicae which extend as far as the parietal wall. Siphonal canal only moderately produced and recurved.

Periostracum light brown in colour, with long brown hairy projections on varices.

**Animal:** Dorsum of foot white, ornamented with cylindrical, hexagonal or round rusty-brown spots, some larger than others. Tentacles whitish, underside translucent light grey; siphon is of the same pattern as the foot on the underside, top is translucent-white.

**Radula:** Radular ribbon white, 3.0 mm long and 0.23 mm wide in an animal with a shell 45.0 mm in length; fully

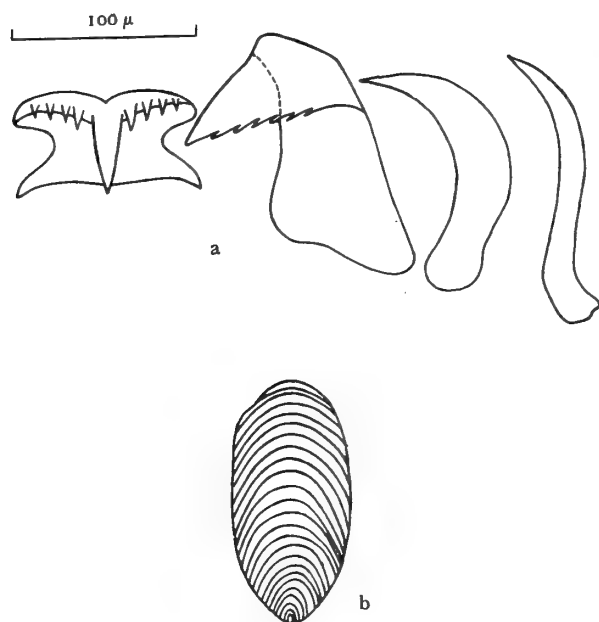


Figure 10

*Cymatium pileare* (LINNAEUS). Fiji Islands.

a. Half Row of Radular Teeth

b. Operculum

formed rows number 61 (+ 7 nascentes), and appreciable wear is evident in anterior rows of the ribbon. Rhachidian laterally deeply excavated, equipped with a massive central cusp and 4 accessory cusps at the sides. Laterals broad, with 6 accessory cusps on cutting edge; inner and outer marginals simple and without accessory cusps.

**Size:** 37 to 103 mm.

**Habitat:** Under coral rocks, on sand and coral substrate, in shallow water.

**Common.**

**Distribution:** Throughout the Fiji Islands. – From the Red Sea through the tropical Indo-Pacific to Polynesia, the Hawaiian Islands, and the Caribbean region.

**Discussion:** LINNAEUS' (1758) habitat indication "*M. Mediterraneo*" is incorrect.

#### 8. *Cymatium pyrum* (LINNAEUS, 1758)

(Plate 45, Figure 19)

1758. *Murex pyrum* LINNAEUS, Syst. Nat., ed. 10, p. 749

1798. *Cymatium clavatum* RÖDING, Mus. Bolten., p. 129  
 1798. *Cymatium canaliculatum* RÖDING, Mus. Bolten., p. 129  
 1798. *Cymatium caudatum* RÖDING, Mus. Bolten., p. 129 (non *Murex caudatus* GMELIN, 1791)  
 1798. *Cymatium flexuosum* RÖDING, Mus. Bolten., p. 129  
 1798. *Cymatium muricatum* RÖDING, Mus. Bolten., p. 130

**Shell:** Shell moderately large, heavy and solid; reddish-orange in colour, irregularly mottled with white on varices. Whorls angulate, numbering 5 - 6 apart from protoconch of 2 whitish nuclear whorls; 2 varices are situated at each whorl, and about 5 prominent and angulate knobs are positioned between varices. Body whorl sculptured with 14 - 15 spiral cords, about 6 of which are heavy ridges, penultimate and earlier whorls with 2 - 3 strong cords; numerous close-set and finely beaded spiral cords are interspersed between the heavy cords, and interstices are finely axially striate. Outer lip with about 7 - 8 prominent reddish-orange denticles which extend as strong white plicae towards the interior of the aperture; interstices of denticles reddish-orange. Columella with 16 to 18 strong white plicae, 1 denticle at parietal wall, interstices orange-red. Anal canal almost obsolete, Siphonal canal thickened, moderately long, twisted and recurved; interior of aperture white.

**Size:** 60 to 95 mm.

**Habitat:** Unknown. Known from collection of dead but well-preserved specimens.

**Rare.**

**Distribution:** South Viti Levu and the Yasawa Islands. Throughout the tropical Pacific.

#### 9. *Cymatium rubeculum* (LINNAEUS, 1758)

(Plate 44, Figure 13; Text figure 11)

1758. *Murex rubecula* LINNAEUS, Syst. Nat., ed. 10, p. 749  
 1798. *Tritonium limbatum* RÖDING, Mus. Bolten., p. 126  
 1798. *Tritonium flaveola* RÖDING, Mus. Bolten., p. 127  
 1811. *Septa scarlatina* PERRY, Conchology, pl. 14, fig. 2  
 1816. *Triton nubecula* [sic] LAMARCK, Tabl. Encycl. Méth., p. 4, pl. 413, figs. 2 a, 2 b

**Shell:** Shell moderately small and rather solid; variable in colour, but generally bright or dark red, ornamented with an occasional whitish or yellowish transverse band on body whorl and small patches of white on varices. Shell with 6 convex whorls, one varix at each whorl,

### Explanation of Plate 44

- Figure 13: *Cymatium rubeculum* (LINNAEUS). Fiji. x 1.7  
 Figure 14: *Cymatium hepaticum* (RÖDING). Fiji. x 1.7  
 Figure 15: *Cymatium vespaceum* (LAMARCK). Fiji. x 1.8

- Figure 16: *Cymatium* cf. *C. gracile* (REEVE). Fiji. x 1.9  
 Figure 17: *Cymatium gemmatum* (REEVE). Fiji. x 2.4  
 Figure 18: *Cymatium muricinum* (RÖDING). Fiji. x 1.2



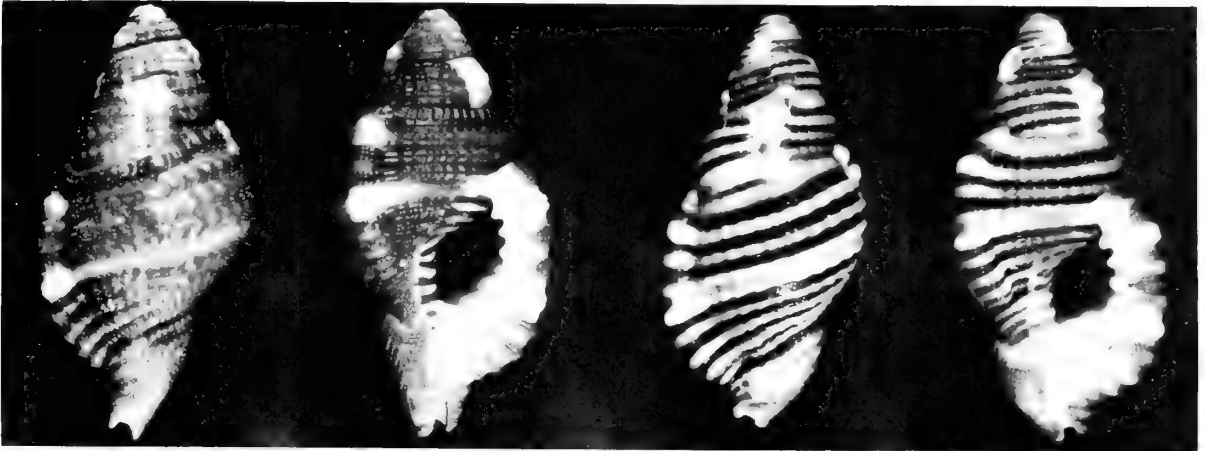


Figure 13

Figure 14



Figure 15

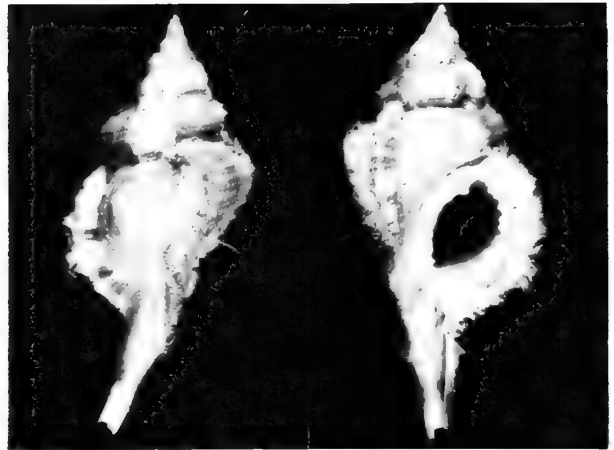


Figure 16



Figure 17

Figure 18



protoconch with 3 - 3½ white, glassy and smooth nuclear whorls; body whorl sculptured with 10 - 16 beaded spiral lirae, penultimate whorl with 3 - 4 lirae; axial grooves descend onto the spiral ridges, and interstices are sculptured with 2 - 4 rows of minute crenules. Outer lip thickened, ornamented with 8 - 10 prominent white denticles which extend towards the interior of the aperture; columella reddish and with 14 - 18 white plicae extending towards the interior of the aperture and siphonal canal. Interior of aperture white or bluish-white, siphonal canal moderately short and recurved.

Periostracum yellowish-brown, tufted, arranged in longitudinal rows following axial striae.



Figure 11

Operculum of *Cymatium rubeculum* (LINNAEUS). Fiji Islands.

In juvenile shells 4 fully formed and 4 nuclear whorls were counted; nuclear whorls were crimson in colour, with the ultimate two nuclear whorls finely spirally striate.

Size: 20 to 50 mm.

Habitat: Under coral rocks, on coral substrate, in shallow water.

Uncommon.

Distribution: Throughout the Fiji Islands. - From East Africa through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

#### 10. *Cymatium vespaceum* (LAMARCK, 1822)

(Plate 44, Figure 15)

1822. *Triton vespaceum* LAMARCK, Anim. sans Vert., 7: 185

1932. *Cymatium vespaceum* [sic] TURTON, Mar. shells Prt. Alfred p. 111

Shell: Shell moderately small, light in weight, spire recurved; fawn to blackish-brown in colour, ornamented with a yellow or whitish peripheral band on body whorl and at sutures; some ridges are lighter coloured and occasional ridges on varices are mottled with white. Whorls angulate, numbering 5 - 6 apart from protoconch;

whorls with one prominent varix, early whorls and penultimate whorl with 2 main elevated spiral ridges and finer intermediate beaded spiral lirae. Body whorl with 25 - 30 spiral ridges and numerous fine axial striae which bisect ridges to form small beads at the summits. Outer lip with 14 - 16 white denticles arranged in pairs; columella whitish and with 12 - 15 white denticles which become plicae on columellar wall; denticle on parietal wall generally prominent. Anal canal only moderately pronounced, siphonal canal slender and moderately long, interior of aperture light greyish-brown.

Size: 26 to 43 mm.

Habitat: Dredged on coral and sand substrate in 7 fathoms.

Moderately rare.

Distribution: Throughout the Fiji Islands. - From South Africa to Polynesia.

#### 11. *Cymatium cf. gracile* (REEVE, 1844)

(Plate 44, Figure 16)

1844. *Triton gracilis* REEVE, Conch. Icon., *Triton*, pl. 15, figs. 58 a, 58 b

Shell: Shell moderately small and light in weight; orange-brown in colour, ornamented with an occasional white spiral ridge on body whorl and varices. Whorls convex, numbering 5 apart from protoconch of 4 glassy-fawn smooth nuclear whorls which are encircled by a faint white transverse band; shell with 2 varices at every whorl, and 2 - 4 knobs or elevated axial ridges are situated between varices. Body whorl with about 25 finely beaded spiral ridges and about 9 such ridges on the penultimate whorl. Interstices of spiral cords with wide-spaced axial grooves and 1 - 2 minute spiral lirae and pittings. Outer lip white, sculptured with 17 small denticles which are arranged in pairs; columella white and calloused, ornamented with 15 prominent white denticular plicae which extend towards the interior of the aperture; one prominent denticle is situated on the parietal wall. Siphonal canal slender, twisted and moderately produced, anal canal obsolete, interior of aperture brownish.

Periostracum yellowish-brown and smooth, except on varices where hairy projections of varying size are visible.

Size: 42 to 46 mm.

Habitat: Dredged in 5 - 8 fathoms on sand and coral rubble substrate.

Very rare.

Distribution: South and West Viti Levu.

Discussion: This species also resembles in some respect *Cymatium pfeifferianum* (REEVE, 1844), a species which

has been recorded from South Africa to the Hawaiian Islands.

*Gyrineum* LINK, 1807

*Gyrineum* LINK, 1807, Besch. Nat.-Samml. Univ. Rostock, p. 123  
 - Type species by SD (DALL, 1904) *Gyrineum verrucosum*  
 LINK, 1807 = *Gyrineum gyrinum* (LINNAEUS, 1758)

**Characters:** Shells small to moderate in size, flatly compressed, whorls convex, varices continuous and vertically aligned, occasionally wing-like, sculptured with spiral rows of nodules. Aperture shorter than the spire, roundly ovate to obliquely oval, labrum and columella denticulate or plicate; anal canal obsolete, siphonal canal short or moderately produced and recurved. Periostracum orange-brown, moderately thin and with hair-like projections on varices.

Operculum orange-brown to brown, moderately thin, ovate, occasionally angulate anteriorly, nucleus terminal and at edge of margin.

Animal similar to other Cymatiidae.

Rhachidians of radular ribbon almost quadrate, only slightly broader than long, concave at base and concavely excavated towards top of plate; central cusp only moderately long, with 5 - 6 very small denticles at either side; laterals broad, inner and outer marginals simple, with or without accessory cusps on cutting edge.

**Discussion:** ROVORETO's type-designation in 1899 of *Gyrineum spinosum* (DILLWYN, 1817) as type species of *Gyrineum* LINK, 1807 is invalid, as this species was not among the originally included species of the genus. The type species of *Apollon* MONTFORT, 1810 is *A. gyrinus* (= *Murex gyrinus* LINNAEUS), and the genus is therefore synonymous with *Gyrineum* LINK. The species *Gyrineum spinosum* (= *G. echinatum* LINK, 1807) belongs to the genus *Bufo* SCHUMACHER, 1817.

12. *Gyrineum gyrinum* (LINNAEUS, 1758)

(Plate 45, Figure 21; Text figure 12)

1758. *Murex gyrinus* LINNAEUS, Syst. Nat., ed. 10, p. 748

1807. *Gyrineum verrucosum* LINK, Besch. Nat.-Samml. Univ. Rostock, p. 123 (non *Tritonium verrucosum* LINK, 1808; nec *Ranella verrucosa* SOWERBY, 1836)

1816. *Ranella ranina* LAMARCK, Tabl. Encycl. Méth., p. 4, pl. 412, figs. 2a, 2b

**Shell:** Shell moderately small, depressed, fairly light in weight; basic colour white or creamy-white, ornamented with 2 - 3 blackish transverse bands on body whorl and a single band on preceding whorls; nodules and parts of varices mottled with yellow or orange. Whorls convex, numbering from 6 - 7 apart from protoconch of 2 nuclear whorls; two varices at every whorl, varices in vertical alignment. Sculpture consists of 9 - 11 spiral rows of wide-spaced rounded beads on body whorl, and 4 rows of beads on penultimate whorl; finer spiral and axial striae are situated in interstices. Aperture white, outer lip with 7 - 8 denticles; columella slightly calloused and with 12 - 16 weak plicae which terminate in two coarse denticular plicae on parietal wall. Siphonal canal moderately short, interior of aperture white or bluish-white.

**Animal:** Foot cream in colour, tentacles small and broad at base, variegated with dark fawn and spotted with white, eyes dark purple. Proboscis very thick (7.4 mm long and 3.5 mm wide), cream coloured, flecked with fawn and white.

Penis club-shaped, yellow in colour, axially streaked with fawn, 6.0 mm long in an animal with a shell 25.0 mm in length.

**Radula:** Radular ribbon translucent white, 10.5 mm long and 0.7 mm wide in an animal with a shell 25.0 mm in length; fully formed rows number 59 (+ 4 nascentes), and wear is discernible in the first 10 anterior rows of teeth. Rhachidian roughly trapezoidal, equipped with one moderately large cusp which is flanked by 5 - 6 very small accessory cusps. Lateral broad and with a long cutting cusp, inner and outer marginals sickle-shaped; laterals and marginals lack accessory cusps on cutting edge.

**Size:** 20 to 46 mm.

**Habitat:** Under coral rocks, on sand and coral substrate, in shallow water; preferred habitats are muddy-sand localities.

Moderately common.

**Distribution:** Throughout the Fiji Islands. - From Indonesia to Polynesia.

**Discussion:** LINNAEUS' habitat indication "*M. Mediteraneo*" is incorrect.

The radula confirms the placing of the species in the family Cymatiidae, not in the Bursidae. The radula is basically of the same pattern as that of *Argobuccinum argus* (GMELIN, 1791) [= *Gyrineum pustulosum* (SOLLANDER in LIGHTFOOT, 1786)] as figured by BARNARD

Explanation of Plate 45

Figure 19: *Cymatium pyrum* (LINNAEUS). Fiji. x 1.0

Figure 20: *Cymatium caudatum* (GMELIN). Fiji. x 1.2

Figure 21: *Gyrineum gyrinum* (LINNAEUS). Fiji. x 2.0

Figure 22: *Gyrineum pusillum* (BRODERIP). Fiji. x 1.0

Figure 23: *Distorsio anus* (LINNAEUS). Fiji. x 1.0

Figure 24: *Distorsio reticulata* RÖDING. Fiji. x 1.0

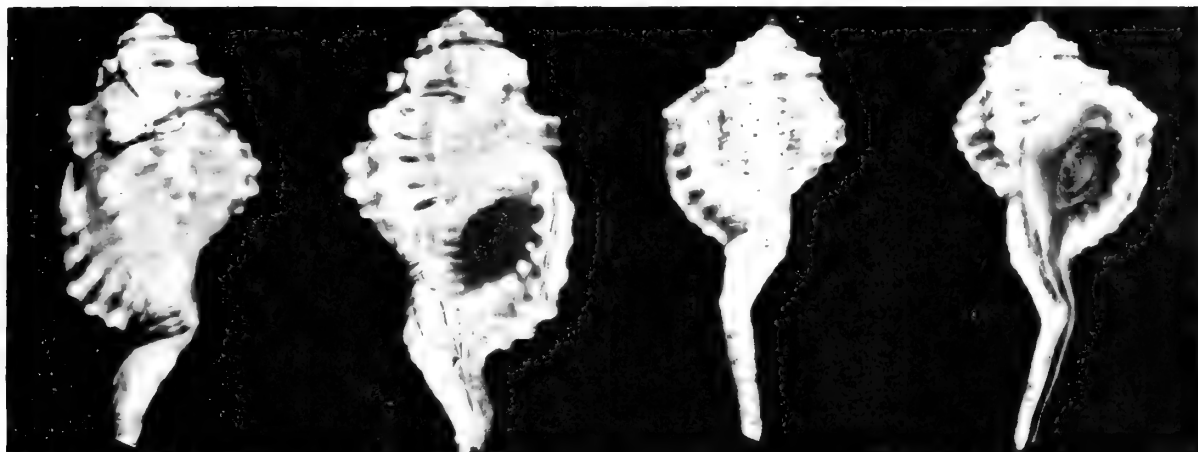


Figure 19

Figure 20

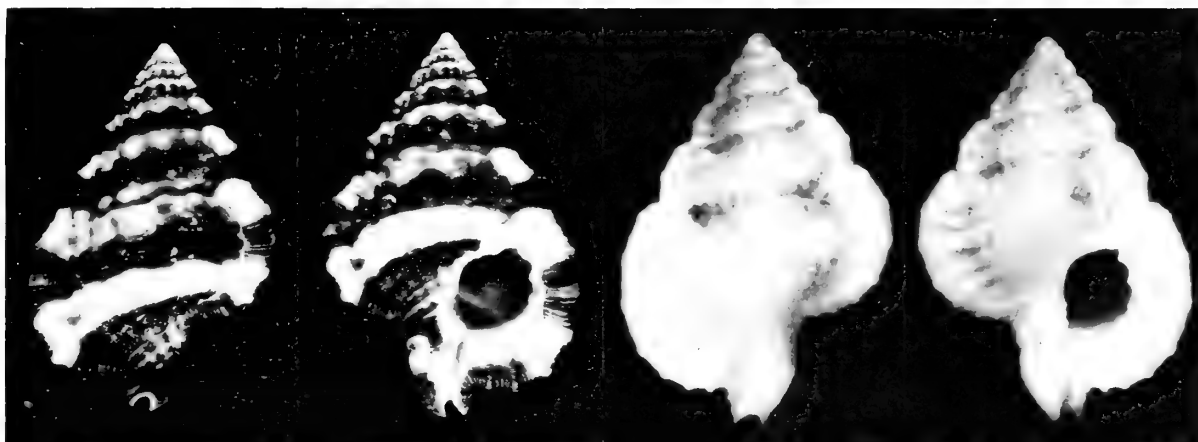


Figure 21

Figure 22

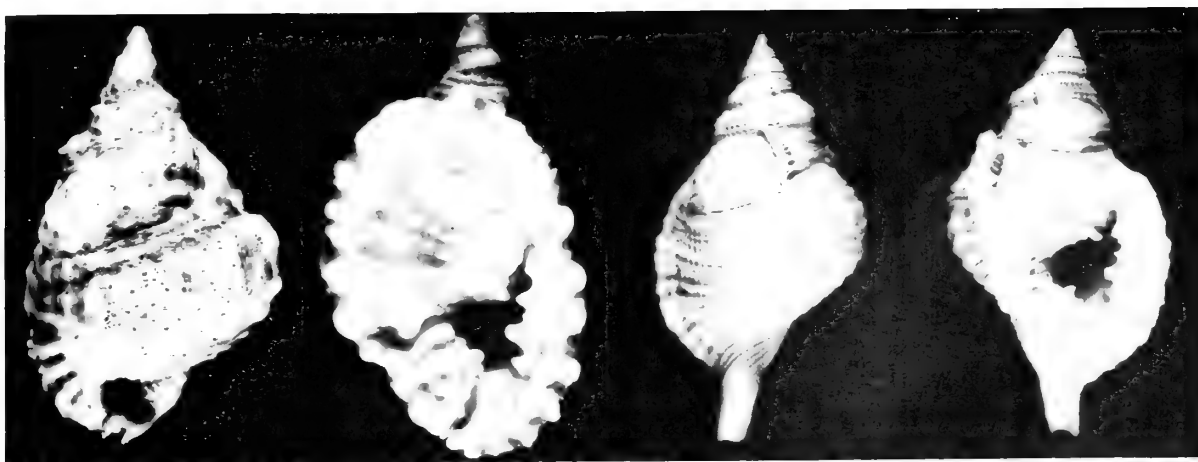


Figure 23

Figure 24



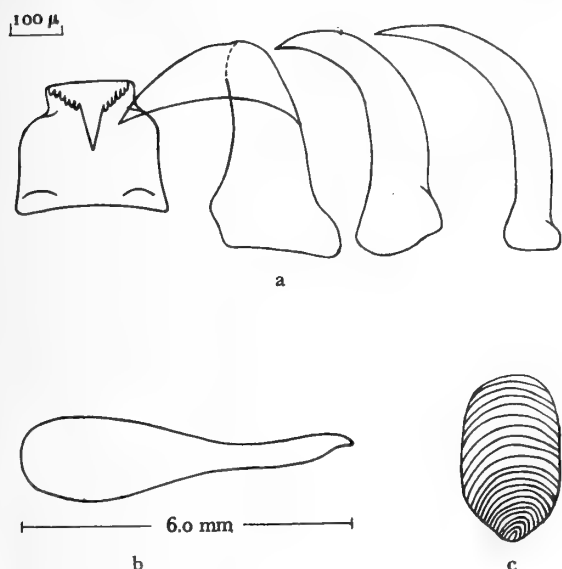


Figure 12

*Gyryneum gyrynum* (LINNAEUS). Fiji Islands.

a. Half Row of Radular Teeth. b. Penis c. Operculum

(1963, p. 19, fig. a). The lack or presence of denticles on the cutting edge of the main cusp of the lateral tooth is variable within species of a genus, and *Argobuccinum* HERRMANNSEN, 1847 (type species *Murex argus* GME-LIN) is on radula evidence synonymous with *Gyryneum* LINK.

13. *Gyryneum pusillum* (BRODERIP, 1832)

(Plate 45, Figure 22)

1832. *Ranella pusilla* BRODERIP, Proc. Zool. Soc. London, p. 1941845. *Triton lacunatum* MICHÈLS, Proc. Bost. Soc. Nat. Hist., 2: 241868. *Triton laciniatum* PEASE, Amer. Journ. Conch., 4: 107

**Shell:** Shell very small, laterally compressed and solid; white or creamy-white in colour, generally ornamented with brown spiral lines or narrow transverse bands. Whorls convex, numbering 6 apart from protoconch of 2 glassy-white nuclear whorls; varices flat, aligned vertically and continuous, numbering 2 at every whorl. Sculpture consists of from 10-12 prominent spiral ridges on the body whorl and 3 ridges on the penultimate whorl; spiral ridges are bisected by 20-22 axial ridges on the penultimate and body whorls, giving the shell a nodulose appearance. Interstices are finely spirally and axially striate. Aperture violet, outer lip with 7-8 denticles; columella with 4-5 plicae, columellar wall obsoletely plicate, parietal wall with 1 or 2 white and small denticles.

Siphonal canal moderately short, deep interior of aperture white.

**Size:** 14 to 23 mm.

**Habitat:** Unknown. Known from collection of dead specimens only.

**Rare.**

**Distribution:** North and West Viti Levu. - From the Seychelles Islands through the tropical Indo-Pacific to Polynesia.

**Discussion:** *Gyryneum roseum* (REEVE, 1844) appears to be a distinct species, which is more brightly coloured and has coarser spiral sculpture.

*Distorsio* RÖDING, 1798

*Distorsio* RÖDING, 1798, Mus. Bolten., p. 133 - Type species by SD (PILSBRY, 1922) *Distorsio anus* (LINNAEUS, 1758)

**Characters:** Shells moderate in size, whorls irregular, convex or angulate, varices discontinuous; sculpture consists of prominent, few or numerous spiral and axial cords. Aperture irregular, constricted, labrum and columella heavily calloused and irregularly dentate and noded, siphonal canal moderately produced and recurved. Periostracum yellowish-brown to dark brown, equipped with hairy projections.

Operculum is greyish-brown, coarse and thick, corneous, irregularly annular, roundly pointed posteriorly, nucleus central and offset towards the left margin.

The rhachidian of the radular ribbon is short and broad, trapezoidal in outline, with a large central cusp and 4-5 small accessory cusps at either side; laterals with a very solid base, and 6-7 small accessory cusps on the cutting edge of the large cusp; inner and outer marginals simple and without accessory cusps.

**Discussion:** THIELE (1929) described the radula of *Distortrix* LINK, 1807 (= *Distorsio* RÖDING) as having rhachidians only slightly less excavated laterally and stated that otherwise the radula is similar to that of *Cymatium* RÖDING. The radula of *Distorsio anus* (LINNAEUS), however, is quite dissimilar compared with that of *Cymatium*, and the lateral margins of the rhachidians are not at all excavated.

14. *Distorsio anus* (LINNAEUS, 1758)

(Plate 45, Figure 23; Text figure 13)

1758. *Murex anus* LINNAEUS, Syst. Nat., ed. 10, p. 7501811. *Distorta rotunda* PERRY, Conchology, pl. 10, fig. 21817. *Distorta rugosa* SCHUMACHER, Essai Nouv. Syst., p. 249

**Shell:** Shell moderate in size, solid and heavy; creamy white in colour, ornamented with irregular broad brown

transverse bands. Whorls angulate, numbering from 6-7 apart from protoconch; varices indistinct, one at every whorl, and 7-10 small knobs are positioned between varices on the body whorl; whorls sculptured with spiral and axial ridges. Outer lip calloused, white or fawn in colour, ornamented with irregular white denticles and

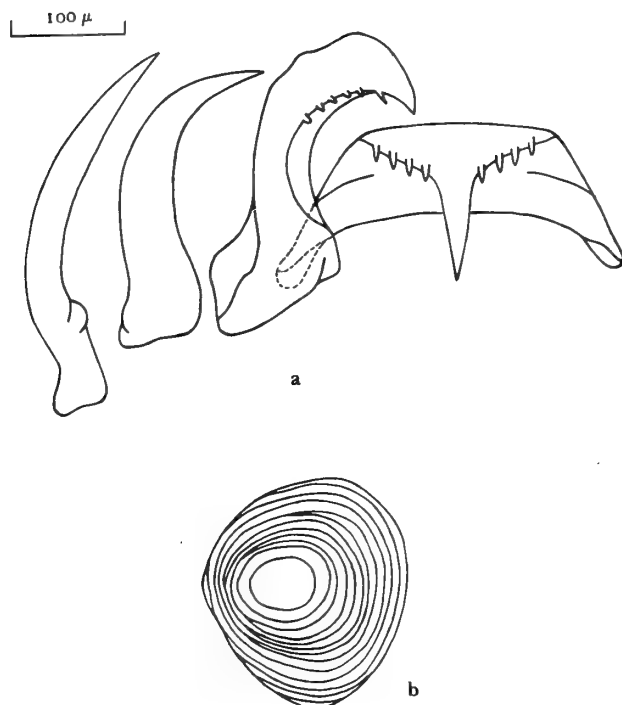


Figure 13

*Distorsio anus* (LINNAEUS). Fiji Islands.

a. Half Row of Radular Teeth

b. Operculum

dark fawn interstices. Columella with a wide flaring and calloused area which is fawn in colour with numerous white patches and irregular nodules. Siphonal canal short, denticulate and recurved almost 90° to the axis of the shell.

**Radula:** Radular ribbon translucent-white in colour, 6.4 mm long and 0.65 mm wide in an animal with a shell 54 mm in length; fully formed rows number 121 (+10 nascentes) and wear was discernible in the anterior rows of teeth. Rhachidians broader than long, equipped with

a long and strong central cusp which is flanked by 4 accessory cusps. Laterals with about 6 cusps on the cutting edge of the main cusp, base broad and solid; inner and outer marginals simple and without accessory cusps. **Size:** 40 to 90 mm.

**Habitat:** Under coral rocks on coral substrate, in shallow water.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - From East Africa through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

### 15. *Distorsio reticulata* RÖDING, 1798

(Plate 45, Figure 24)

1798. *Distorsio reticulata* RÖDING, Mus. Bolten., p. 133

1798. *Distorsio clatrata* RÖDING, Mus. Bolten., p. 133

1803. *Murex cancellinus* LAMARCK, Ann. Mus. Hist. Nat., 2: 225

1844. *Triton decipiens* REEVE, Conch. Icon., Triton, p. 102, pl. 20, sp. 102

1930. *Distorsio francesae* IREDALE, Rec. Austral. Mus., 18: 213, pl. 23, fig. 2

**Shell:** Shell moderate in size, fairly light in weight; cream to light yellow in colour throughout, occasionally with 2-3 yellow transverse bands. Whorls angulate, numbering 8-9 apart from protoconch of 3 smooth whorls; one varix is situated at each whorl. Body whorl sculptured with from 9-22 elevated cord-like ridges, penultimate whorl with 4-10 ridges; spiral ridges are intersected by 20-24 axial cords on the body whorl, and 26-35 cords on the penultimate whorl. Small nodules are formed at intersection point of spiral and axial ridges; interstices are minutely clathrate. Outer lip thin and expanded, sculptured with 14-18 elongated denticles; the ultimate 4-5 denticles reach the wall of the anterior canal, and the 4th and 5th denticles are generally larger than remainder. Columella and part of the body whorl heavily calloused, creamy-white in colour, ornamented with 12-15 irregular denticles; columellar wall with 4-5 noduled ridges, parietal wall with a very prominent denticular cord and 2-4 small denticles. Anterior canal moderately long and fairly open, interior of aperture creamy-white.

Periostracum yellowish-brown and tufty, with a few solitary brown and hairy projections.

**Size:** 37 to 78 mm.

### Explanation of Plate 46

Figure 25: *Linatella cingulata* (LAMARCK). Fiji. x 1.3

Figure 26: *Linatella clandestina* (LAMARCK). Fiji. x 1.5

Figure 27: *Charonia tritonis* (LINNAEUS). Fiji. x 0.25

Figure 28: *Colubraria maculosa* (GMELIN). Fiji. x 1.0

Figure 29: *Colubraria tortuosa* (REEVE). Fiji. x 1.7



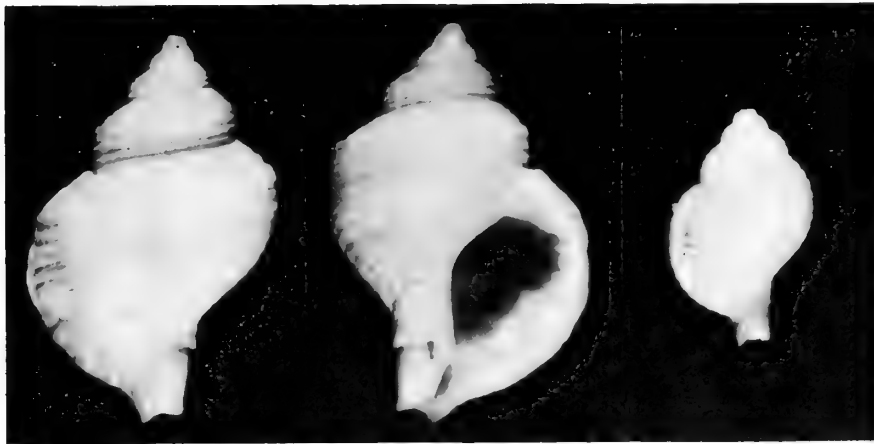


Figure 25

Figure 26

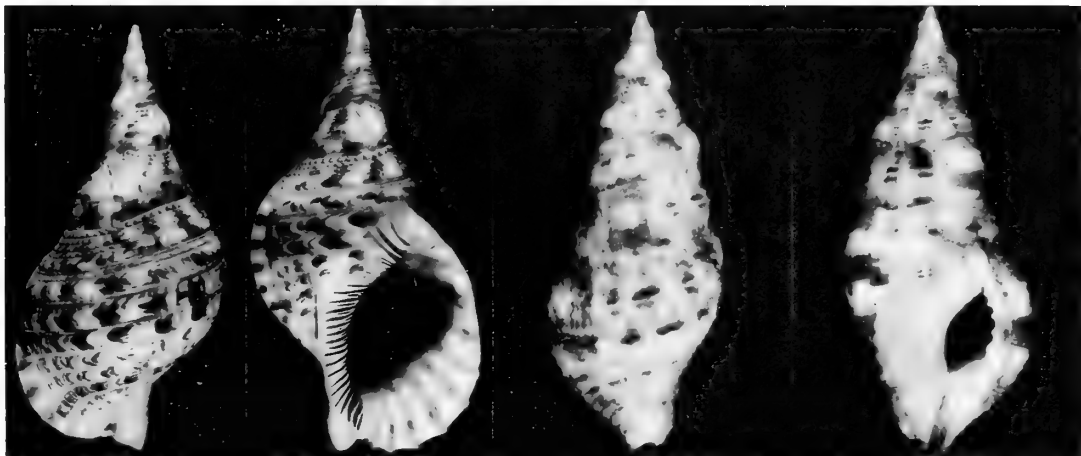


Figure 27

Figure 28

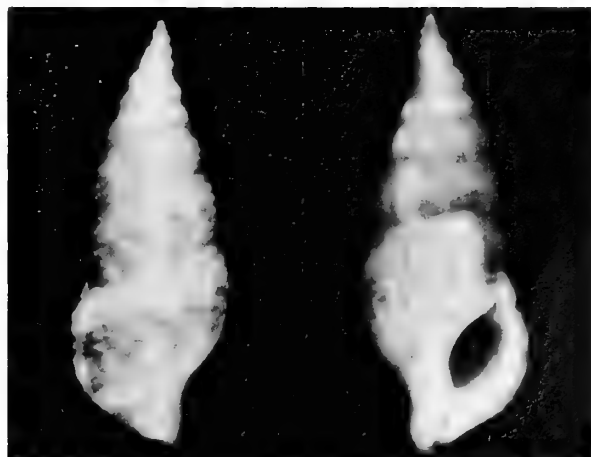


Figure 29



**Habitat:** Under coral rocks on coral substrate, in shallow and deeper water.

Moderately rare.

**Distribution:** Throughout the Fiji Islands. – From the Seychelles Islands through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

*Linatella* GRAY, 1857

*Linatella* GRAY, 1857, Guide Syst. Dist. Moll. Brit. Mus., p. 39 – Type species by M *Linatella cingulata* (LAMARCK, 1822)

**Characters:** Shell dolidiform, light in weight and inflated, moderate in size; whorls irregular and ventricose, convex or angulate, sculptured with strong, flat or rounded spiral cords. Aperture large, labrum reflexed and denticulate, columella calloused and denticulate; siphonal canal broad, moderately short, slightly recurved.

16. *Linatella cingulata* (LAMARCK, 1822)

(Plate 46, Figure 25)

1816. *Fusus cutaceus* LAMARCK, Tabl. Encycl. Méth., p. 6, pl. 427, figs. 4 a, 4 b (non *Murex cutaceus* LINNAEUS, 1767)

1822. *Cassidaria cingulata* LAMARCK, Anim. sans Vert., 7: 216

1839. *Fusus voigtii* ANTON, Verz. Conch., p. 77

1842. *Triton undosum* KIENER, Spéc. Gén. Icon. Coq. Viv., 7: 44, pl. 6, fig. 2 (non LAMARCK, 1816)

1963. *Linatella neptunia* GARRARD, Journ. Malac. Soc. Austral., 7: 43, pl. 7, figs. 7, 8

**Shell:** Shell dolidiform and light in weight; creamy-white in colour, ornamented with 2 obsolete and light brown transverse bands on body whorl; some individuals are light fawn in colour throughout, while others have spiral ridges tinted with light brown. Whorls convexly angulate, ventricose, numbering 5 apart from protoconch; body whorl with 15-17 prominent flattish or rounded spiral cords, penultimate whorl with 6-8 cords. Interstices either smooth or with obsolete spiral striae; the third cord anterior to the suture on the body whorl is generally more prominent and obsoletely nodulose; whorls are crossed by numerous axial growth striae. Outer lip slightly reflexed, sculptured with about 14-15 orange-brown denticles; columella calloused, ornamented with 8-11 denticles. Aperture very wide, interior whitish, siphonal canal broad and recurved.

**Size:** 40 to 55 m.

**Habitat:** Dredged in deeper water on coral sand substrate. Rare.

**Distribution:** West Viti Levu – From Mauritius through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

**Discussion:** *Linatella neptunia* GARRARD was recently described from Queensland, Australia, as a new species differing from *L. cingulata* (LAMARCK) in having rounded ribs and lacking spiral striae in interstices. Specimens of *L. cingulata* from Japan, Fiji and the Hawaiian Islands occasionally show rounded spiral ridges, a feature also evident in the type figure of *L. cingulata* (LAMARCK, 1816, pl. 427, figs. 4 a, 4 b); the interstices are generally smooth but occasionally also spirally striate.

*Fusus cutaceus* LAMARCK, 1816, does not appear to be a secondary homonym of *Murex cutaceus* LINNAEUS, 1767; the latter is the type species of the genus *Cabestana* RÖDING, 1798, and it is somewhat doubtful that *Linatella* and *Cabestana* are congeneric. Since no radula of *Linatella cingulata* was available for comparison, the later Lamarckian name has been retained.

17. *Linatella clandestina* (LAMARCK, 1816)

(Plate 46, Figure 26)

1816. *Triton clandestinum* LAMARCK, Tabl. Encycl. Méth., p. 8, pl. 433, fig. 1

**Shell:** Shell similar to that of *Linatella cingulata*, fawn in colour, ornamented with about 16-18 dark brown spiral cords on body whorl; whorls regularly convex and inflated, penultimate whorl with 6 dark spiral cords. Interstices of spiral cords with irregular axial growth striae. Outer lip with brown denticles, columella plicate, anterior canal longer than in *L. cingulata*, and recurved; interior of aperture white.

**Size:** 27 mm.

**Habitat:** Unknown. The single specimen known was collected dead.

Rare.

**Distribution:** South Viti Levu. – From the Philippine Islands to Polynesia and the Hawaiian Islands.

**Discussion:** The species is known from one small immature specimen from Fiji; the species will attain 65 mm in length. For a recent figure of this species see TINKER (1958), plate facing page 92, centre figure.

*Charonia* GISTEL, 1848

*Charonia* GISTEL, 1848, Nat. Thierr. Schulen, p. 170 – Type species by M *Charonia tritonis* (LINNAEUS, 1758)

**Characters:** Shells moderate to large in size, whorls convex and sometimes irregular, varices prominent and discontinuous; whorls sculptured with broad spiral cords. Aperture large and flaring, labrum plicate, columella plicate or occasionally smooth, siphonal canal moderately produced and recurved.

Operculum is brownish, nucleus terminal or laterally offset to the right.

Egg capsules are deposited directly onto the substrate in a cluster.

18. *Charonia tritonis* (LINNAEUS, 1758)

(Plate 46, Figure 27)

1758. *Murex tritonis* LINNAEUS, Syst. Nat., ed. 10, p. 754

1798. *Tritonium opis* RÖDING, Mus. Bolten., p. 125

1807. *Tritonium marmoratus* LINK, Besch. Nat.-Samml. Univ. Rostock, p. 122

1816. *Triton variegatum* LAMARCK, Tabl. Encycl. Méth., p. 5, pl. 421, figs. 2a, 2b

**Shell:** Shell large, creamy-white or ivory in colour, profusely mottled with dark and light brown. Whorls convex and inflated, numbering about 10 apart from the protoconch; whorls sculptured with broad and flat spiral cords, axial riblets near sutures and intermediate spiral ridges in interstices; early whorls granulose; varices prominent. Aperture wide and flaring, outer lip creamy-white ornamented with obsolete plicae and denticles on labial margin; columella calloused, creamy-white, sculptured with white plicae, interstices of plicae black or dark purple. Siphonal canal short, interior of aperture orange brown.

**Size:** 100 to 400 mm.

**Habitat:** On sand substrate or coral rubble bottom, in deeper water.

Moderately common.

**Distribution:** Throughout the Fiji Islands. – From Madagascar through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands; eastern coast of America and the Caribbean region.

**Discussion:** *Triton* MONTFORT, 1810 (type species *Murex tritonis* LINNAEUS) does not equal *Triton* FLEMING, 1828 (= *Tritonalia* FLEMING, 1828 – Muricidae) as pointed out by DODGE (1957). *Tritonalia* FLEMING, 1828, is rarely used by modern writers for either *Charonia* GISTEL, 1848, or *Ocenebra* GRAY, 1847, and should be rejected officially.

The egg mass of the species consists of about 230 vase-shaped egg capsules, one inch by a quarter inch in size, each capsule containing about 1000 eggs (*vide* Hawaiian Shell News, 1961 and 1966).

COLUBRARIIDAE

*Colubraria* SCHUMACHER, 1817

*Colubraria* SCHUMACHER, 1817, Essai Nouv. Syst., p. 251 – Type species by *M Colubraria granulata* SCHUMACHER, 1817

**Characters:** Shells moderate in size, fusiform, spire longer than aperture, whorls numerous and convex, varices broad and discontinuous; sculpture consists generally of spiral rows of axially oriented nodules or spiral ridges. Aperture moderately small, labrum denticulate, columella calloused, smooth or irregularly dentate or wrinkled; siphonal canal short and recurved.

Operculum orange-brown to brown, corneus, slenderly ovate but slightly irregular, angulate on upper left-hand margin, generally pointed posteriorly, nucleus terminal but ill-defined.

**Discussion:** The genus *Colubraria* has not only been frequently assigned to various families, but has been placed in the groups of rhachiglossate and taenioglossate prosobranchs. SCHEPMAN, 1913, and DEMOND, 1957, assigned the genus to the Buccinidae, IREDALE, 1929, to the Fusidae, KURODA & HABE, 1952, retained the genus in the Cymatiidae, and THIELE, 1929, assigned *Colubraria* as a section of *Charonia* GISTEL, 1848, with a query.

As the soft parts were not available for examination at the time of writing, *Colubraria* has been tentatively retained in the family Colubrariidae.

1. *Colubraria maculosa* (GMELIN, 1791)

(Plate 46, Figure 28; Text figure 14)

1791. *Murex maculosus* GMELIN, Syst. Nat., ed. 13, p. 3548

1798. *Tritonium maculatum* RÖDING, Mus. Bolten., p. 126

**Shell:** Shell moderate in size, solid and heavy; cream in colour, ornamented with about 3 transverse rows of interrupted purplish lines on the body whorl, and obsolete



Figure 14

Operculum of *Colubraria maculosa* (GMELIN). Fiji Islands.

brown zones on whorls and varices. Whorls convex, numbering from 10-11 apart from 2 white nuclear whorls; two prominent varices are situated at every whorl. Sculpture consists of 18-22 spiral ridges on the body whorl and 6-7 ridges on the penultimate whorl; axial ridges descend onto the spiral cords giving the latter a nodulose appear-

ance. Interstices of nodules are sculptured with 6-8 very fine spiral striae and occasionally a small intermediate spiral cord. Aperture cream or creamy-white in colour, outer lip calloused and ornamented with 10-15 whitish denticles which continue as spiral ridges into the aperture; columella heavily calloused, sculptured with 4-5 obsolete plicae, columellar wall almost smooth, parietal wall with 2-3 plicae; siphonal canal moderately short.

**Size:** 40 to 92 mm.

**Habitat:** Under coral rocks, on reef and sand substrate in shallow and deeper water.

Uncommon.

**Distribution:** Throughout the Fiji Islands. - From the Red Sea through the tropical Indo-Pacific to Polynesia and the Hawaiian Islands.

## 2. *Colubraria tortuosa* (REEVE, 1844)

(Plate 46, Figure 29)

1829. *Triton distortum* SCHUBERT & WAGNER, Conch. Cab., 12: 138, pl. 231, figs. 4074, 4075 (non LAMARCK, 1816)

1844. *Triton tortuosus* REEVE, Conch. Icon., *Triton*, pl. 17, sp. 74 a, 74 b

1903. *Tritonium streptum* COSSMANN, Essai Paléo. Comp., 5th livr., p. 93 (nom. nov. pro *Triton tortuosus* REEVE, 1844)

**Shell:** Shell moderate in size, solid and heavy; yellowish, orange or yellowish-brown in colour, ornamented with irregular wavy brownish bands, which are occasionally arranged in 1 or 2 transverse bands on all whorls. Whorls convex, numbering from 8-11 apart from protoconch of 2 glassy-white smooth nuclear whorls; whorls sculptured with 16-24 spiral rows of round or axially oriented small nodules; there is one varix at every whorl, and interstices of nodules are minutely spirally striate. Aperture ivory-white or creamy-white, outer lip calloused and sculptured with 12-17 denticles; columella calloused, creamy-white, with a few small irregular sized nodules, columellar wall finely plicate, parietal wall with 1-2 prominent plicae. Siphonal canal moderately short and slightly recurved, spire generally twisted.

**Size:** 25 to 57 mm.

**Habitat:** Under coral rocks, in shallow and deeper water. Uncommon.

**Distribution:** Throughout the Fiji Islands. - From New Guinea through the tropical Pacific to Polynesia and the Hawaiian Islands.

**Discussion:** Some specimens display one or two narrow brown bands on the body whorl, while others have brown spots arranged in rows.

IREDALE (1929) adopted *Colubraria strepta* (COSSMANN) for this species, in view of the usage of *Triton tortuosus* by BROCCHI. There does not appear to be any

record of *T. tortuosus* BROCCHI in literature, and *Murex tortuosus* BORSONI, 1827 belongs to the genus *Distorsio* RÖDING, 1798; the substitute name *Colubraria strepta* (COSSMANN) is superfluous.

## SUMMARY

The species of the three families recorded to date are only those collected by resident collectors and the author. Museum records have not been taken into consideration.

The comparative rarity of *Colubraria* species in Fiji is somewhat surprising, and it is hoped that additional species will be discovered in the future.

The total number of species recorded in the various genera of the three families is as follows:

BURSIDAE	
<i>Bursa</i>	8
CYMATIIDAE	
✓ <i>Cymatium</i>	11
<i>Gyrinus</i>	2
✓ <i>Distorsio</i>	2
<i>Linatella</i>	2
✓ <i>Charonia</i>	1
Total	18
COLUBRARIIDAE	
<i>Colubraria</i>	2

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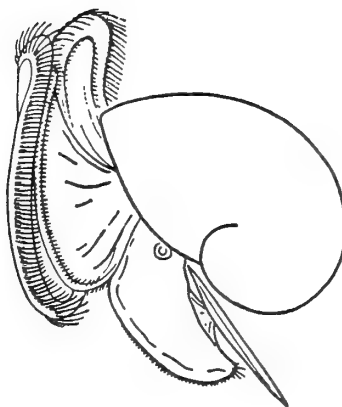
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## Aspects of the Biology of *Donax gouldi* And a Note on Evolution in Tellinacea (Bivalvia)

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(5 Text figures)

### INTRODUCTION

*Donax gouldi* DALL, 1921, is a small bivalve that lives in the surf zone of sandy marine beaches and ranges from Santa Barbara, California, to Acapulco, Mexico. Although the Tellinacea are generally regarded as non-selective deposit feeding organisms, *D. gouldi* feeds in a different manner to be described below.

MORI (1938, 1950), HEDGPETH (1953), TURNER & BELDING (1957), LOESCH (1957), and WADE (1964) have shown that various species of *Donax* maintain their position in the surf zone by horizontal migration with the tide. The adaptations that permit *D. gouldi* to occupy this zone are discussed.

### MORPHOLOGY

**Shell:** As shown in Figure 1 the thick shell of *Donax gouldi* is elongate, being almost twice as long as it is high. This shape is highly adaptive for burrowing movements with the anterior end undermost, as shown for species of *Solen* and *Siliqua* (POHLO, 1963). Most specimens are about 1.5 cm long but can be as large as 2.5 cm.

**Mantle Cavity:** The organs of the mantle cavity are shown in Figure 1. It is seen that the ctenidia (C) are large and the labial palps (LP) small. In many of the Tellinacea the outer demibranch is upturned but this is not the case in *Donax gouldi* in which both demibranchs are complete.

Animals opened in the field had very little sand in the mantle cavity. If sand was present it was usually located at the site of pseudo-feces accumulation or on the foot but rarely on the ctenidia or labial palps. A mantle fold, on the anterior margin of the inhalant siphon in some other Tellinacea, is lacking.

Figures 1 and 3 show the feeding current pattern on the ctenidia and labial palps. The anatomical relationship

of ctenidia and labial palps is of Category III (i. e., the anterior filaments of the inner demibranch are not inserted into a distal oral groove – STASEK, 1963). Material moves rapidly on the outer to the inner demibranch. Some material is carried toward the labial palps along the ventral margins of the outer demibranch but the current is weak and a food groove is absent. Material also goes under the outer demibranch (OD), and then moves dorsally. This same type of movement was observed by YONGE (1949, p. 59, fig. 22 b). There is a well-defined food groove on the inner demibranch (ID), and material is carried in it toward the labial palps. Most of the larger material is rapidly moved by ciliary activity perpendicular to the long axis of the palp folds (Figure 3).

**Pedal Musculature:** The pedal musculature (Figure 1) is more complex than is usually found within the Tellinacea. Here the anterior protractor muscle (AP) is split into three bands at the site of its insertion near the anterior adductor. An elevator pedis muscle (EP) is present, as is a small muscle, here termed the demibranch muscle (DM).

**Siphons:** The inhalant siphon (Figure 2) is ringed with six lobes. These lobes, which are pointed, have many frilly projections emanating from their sides and act as a straining device. The end of the siphon is shown expanded in Figure 2, but in life, the tentacles are usually very close together with little space between the interdigitating frills.

Observations were made on animals kept in a finger bowl half filled with sand. The inhalant siphon was seen to move up and down continually while it pushed aside sand grains. At all times the tentacles on the inhalant siphon were drawn close together and were actively rejecting sand grains. This is in contrast to *Donax vittatus* DA COSTA, where the siphonal tentacles are turned back and the siphons have no sieving action (YONGE, 1949).



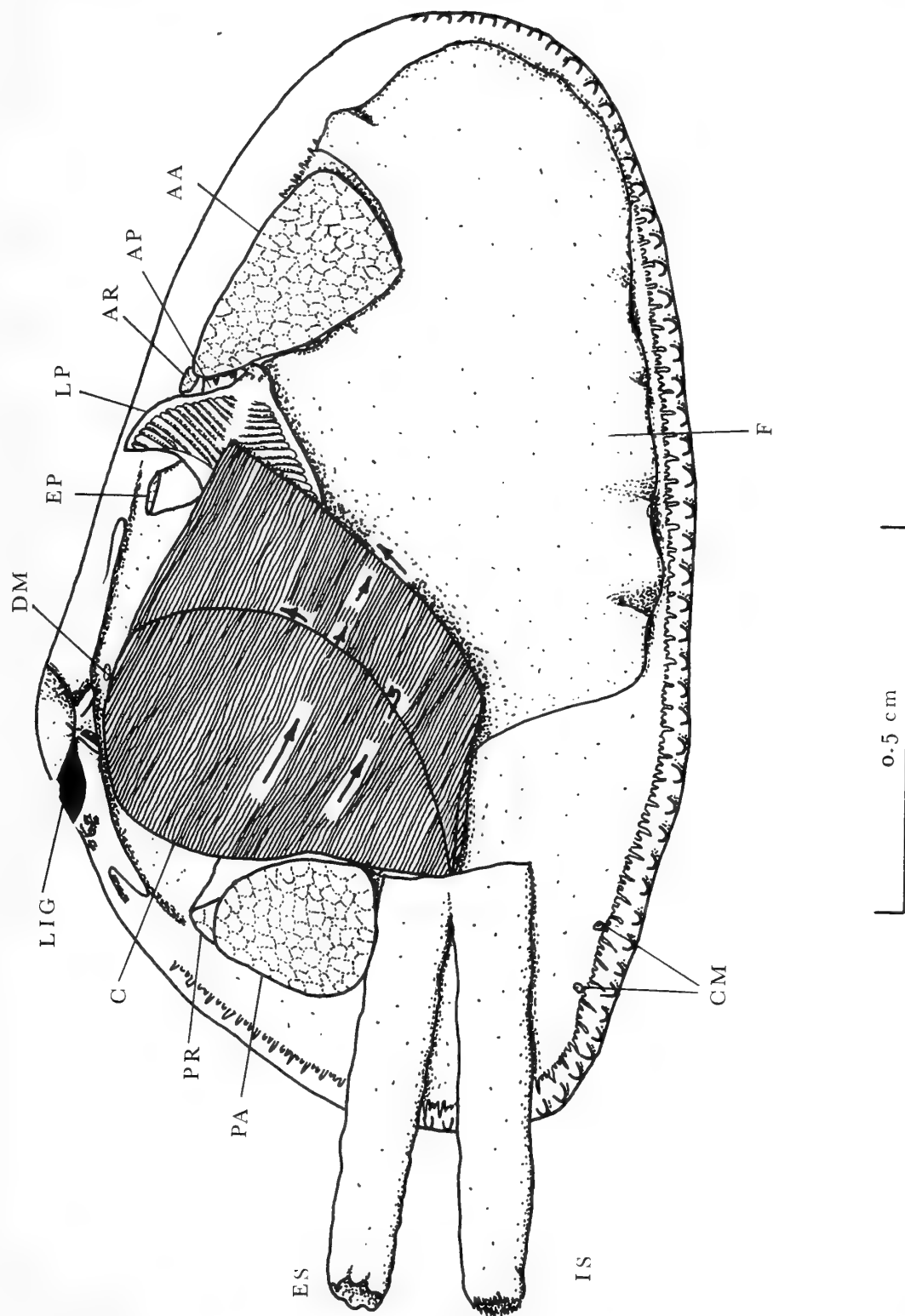


Figure 1

*Donax gouldi*. Mantle Cavity Viewed from the Right Side.

AA - anterior adductor; AP - anterior protractor; AR - anterior retractor; C - ctenidia; CM - cruciform muscle; DM - demibranch muscle; EP - elevator pedis muscle; ES - exhalant siphon; F - foot; IS - inhalant siphon; LIG - ligament; LP - labial palp; PA - posterior adductor; PR - posterior retractor.

The exhalant siphon (ES) of *D. gouldi* terminates in six blunt lobes.

**Stomach:** The terminology used to describe the stomach is that of PURCHON (1957, 1958, 1960).

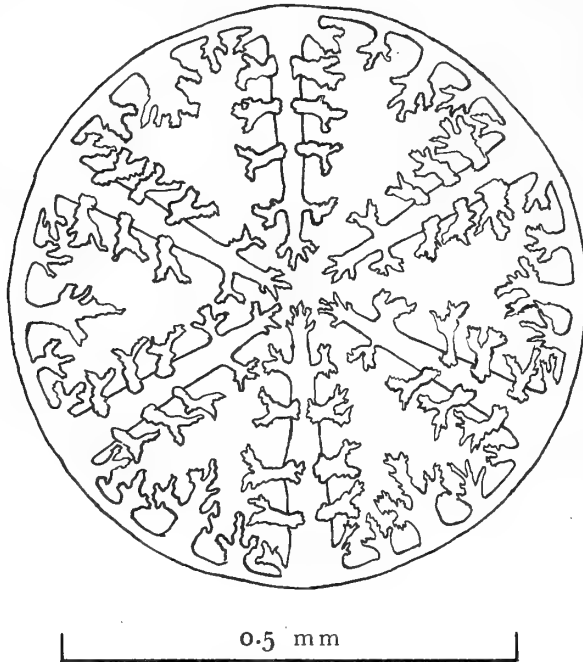


Figure 2

Sieving Mechanisms on the Inhalant Siphon.

The stomach (Figure 4) is of Type IV (characterized by the major typhlosoles not entering any ducts from the digestive diverticulum on the anterior or right side of the stomach). Externally it has a large dorsal hood (DH) and a small postero-dorsal appendix (A). A left caecum (LC) is present and the major typhlosole (TY) leads into it, material being carried on the typhlosole into the caecum.

Rejected material moves on the inner side of the major typhlosole toward the mid gut (MG). The typhlosole thus extends from the left caecum to the intestine. The typhlosole does not enter the digestive diverticulum duct (DDD) as it does in the other Tellinacea (PURCHON, 1960). A large left pouch (LP) is present with its sorting areas (SA), and it has seven openings to the digestive diverticulum. The intestine is separate from the style sac (SS) which is not the situation in most of the Tellinacea studied by PURCHON (1960). There are some differences between *Donax gouldi* and *D. faba* GMELIN (described

by PURCHON, 1960). The left caecum (LC) of *D. gouldi* receives seven ducts from the digestive diverticulum, whereas in *D. faba* there are only four. The appendix is much smaller in *D. gouldi*, and there is no sorting area no. 3 (see PURCHON, 1960, fig. 2).

The stomach contents of *Donax gouldi* were mainly green fragmented plant material, diatoms and some small sand grains. This is in contrast to *Macoma secta* which also lives in a sand substratum. In this species, the stomach is densely packed with relatively large sand grains.

### MOVEMENT AND MAINTENANCE OF POSITION IN THE SURF ZONE

MORI (1938, 1960), HEDGPETH (1953), TURNER & BELDING (1957), LOESCH (1957) and WADE (1964) have described how various species of *Donax* migrate with the rise and fall of the tide. These authors concluded that the clams emerge from the sand when triggered by acoustic shocks made by the breaking waves. The bivalves are then carried up or down the beach by the wave swash, and in this manner they maintain their position in the wave and swash zone.

*Donax gouldi* does not migrate with the rise and fall of the tide but stays in one position on the beach. This is in opposition to a study done by JOHNSON (1966) where she found that *D. gouldi* exhibits the migration tendency, but to a lesser degree, as found in *D. fossor* SAY, 1823, *D. semigranosus* DUNKER, 1877 and *D. variabilis* PHILIPPI, 1847. The absence of migration was seen by noting the behavior of this organism at San Diego and Los Angeles, California, and at Estero Beach, Mexico, where a very dense population was studied. At the Mexico locale the animals were so densely packed that many were protruding half out of the sand due to the lack of digging space. A similar population was reported at La Jolla, California, by COE (1953). These exposed animals made it easy to gauge the gross extent of the aggregation. They occurred in a band about 10m wide at a tidal height of about one-half a foot below mean lower low water. When encountered on a minus tide at Estero Beach, the main population was completely separated from the swash zone by a distance of 15m. This was taken as evidence that the animals do not maintain a position in the swash zone by migration.

Whereas migrating *Donax* pop out of the sand when a shock goes through the substratum, *D. gouldi* digs farther into the soil. This was seen by taking 33 specimens and placing them in a water and sand filled bucket. One

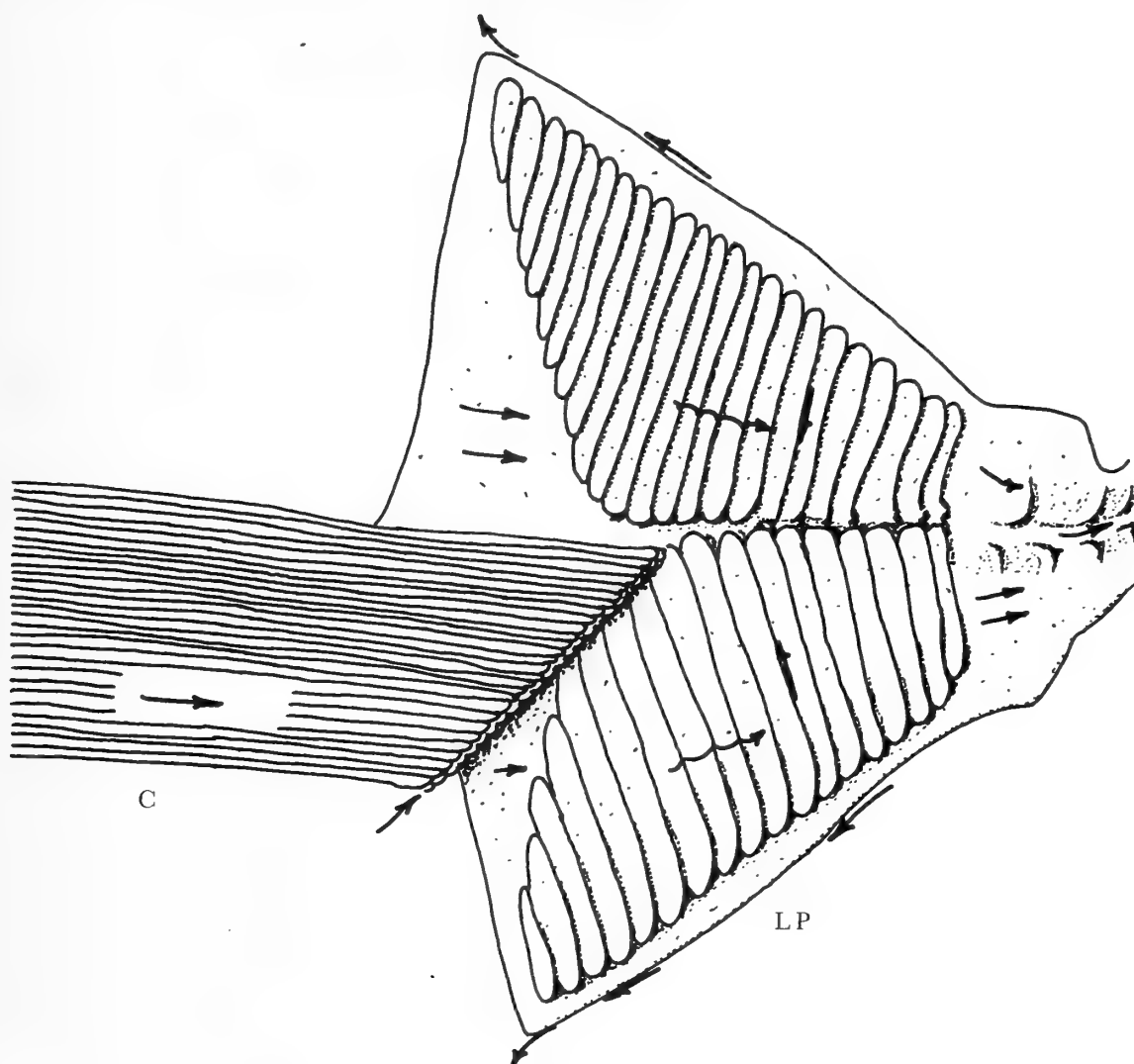


Figure 3

Feeding Currents on the Labial Palps (LP).

Most of the material is carried on the current perpendicular to the long axis of the palp folds. G - gills.

animal began to burrow immediately, but the remainder did not burrow until the side of the bucket was pounded. After agitating the bucket, all but 10 burrowed into the sand. The most effective stimulus for burrowing seemed to be a combination of agitating the animal and rolling it about in a stream of water, conditions which occur naturally in the surf zone.

On the beach, when *Donax gouldi* happens to be unearthed by waves they extend their siphons and foot and

these act as a drag preventing the animal from being carried the full advance of the swash. The foot, particularly, does an effective job of acting as a drag. JACOBSON (1955) has described a similar behavior in *D. fossor*. In *D. gouldi*, as soon as the individual wave has subsided enough, the unearthed animal begins to flatten the foot against the substratum and then insert it into the sand as the siphons are being withdrawn. The animal then rapidly

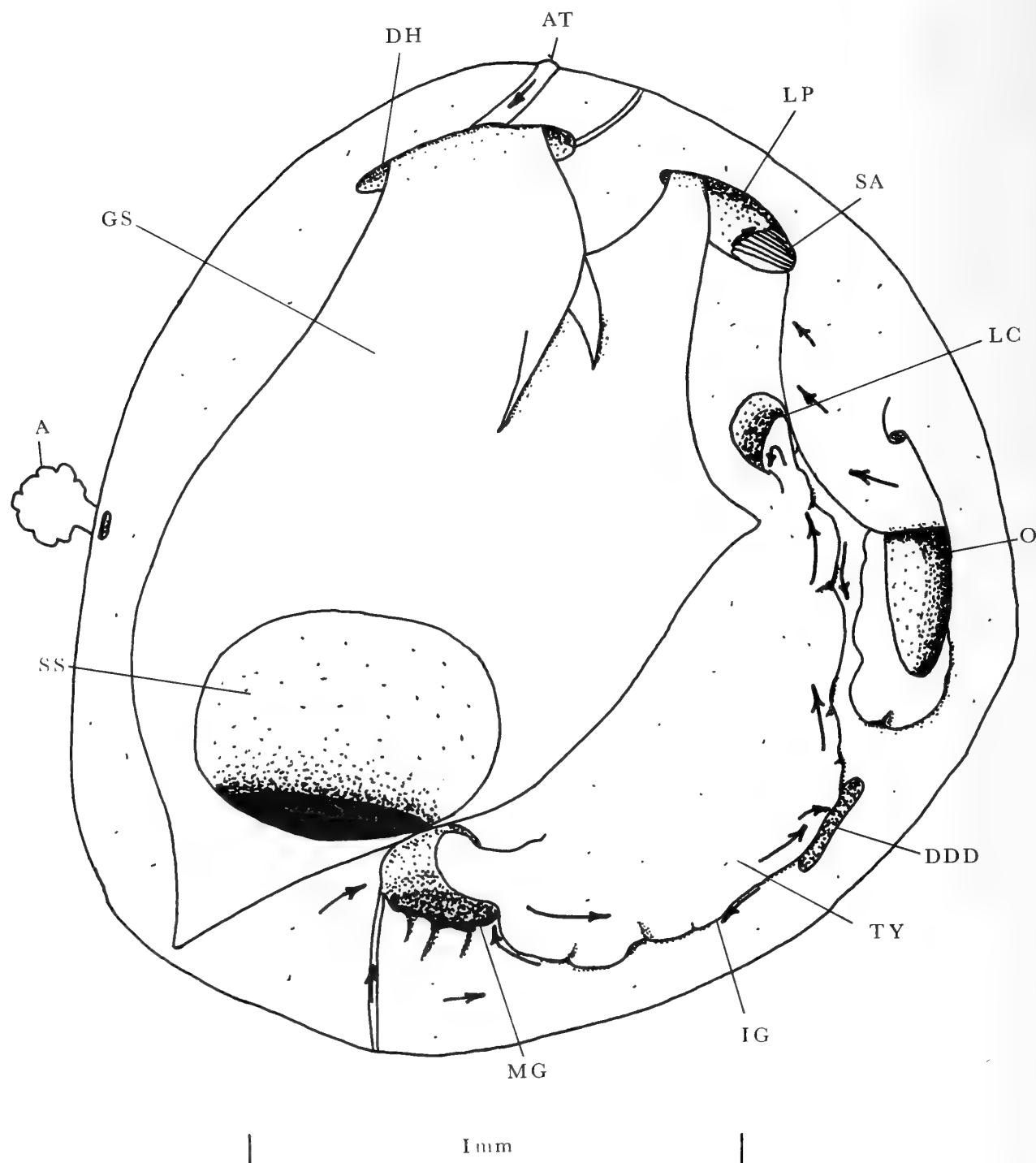


Figure 4

The Stomach of *Donax gouldi* after Dissection from the Dorsal Side.

A - appendix; AT - acceptance tract; DDD - digestive diverticular duct; DH - dorsal hood; GS - gastric shield; IG - intestinal groove; LC - left caecum; LP - left pouch; MG - mid gut; O - oesophagus; SA - sorting areas; SS - style sac; TY - major typhlosole.

rocks back and forth and is buried by a combination of its digging movements and a scouring of the sand, which is described by JOHNSON (1957).

To obtain an estimate of the density of the population at Estero Beach, random samples were taken within the 10 meter wide band. A metal frame 10 cm on a side was inserted to a depth of 1 cm and then a metal plate was inserted under the frame. Twenty samples were taken and the number of animals per quadrant ranged from 162 to 521. The average was  $322.1 \pm 18.76$  animals per 100 cm<sup>2</sup> of surface area. This is larger than the density of 20000 per m<sup>2</sup> found by COE (1953), although he gives no standard error of the estimate.

### DISCUSSION AND CONCLUSIONS

An examination of the anatomy and behavior of *Donax gouldi* reveals that this species feeds on material suspended in the water and not on deposits. This is evidenced by the efficient straining mechanism on the inhalant siphon (Fig-

ure 3), by the general absence of sand grains within the mantle cavity and by an examination of the stomach contents. A similar feeding habit was outlined for *D. denticulatus* (LINNAEUS) by WADE (1964). These species feed differently than *D. vittatus* (YONGE, 1949), where there is no straining mechanism on the inhalant siphon, and the tentacular lobes are curled back, permitting suspended material along with some deposits to enter freely.

This evidence removes another species of the Tellinacea from the deposit-feeding ranks (see POHLO, 1966, with regard to feeding in *Tagelus californianus*). YONGE (1949, p. 39) states that *Donax vittatus* feeds primarily on suspended material but later (p. 433) he states "Like all Tellinacea, these animals [referring to *Tagelus californianus*] are deposit feeders." Subsequent authors, for example, STASEK (1961), have been misled in the belief that deposit-feeding is universal within the Tellinacea.

Certain features of the morphology of *Donax gouldi* are associated with suspension-feeding, and are not generally found in the deposit-feeding Tellinacea. The animal

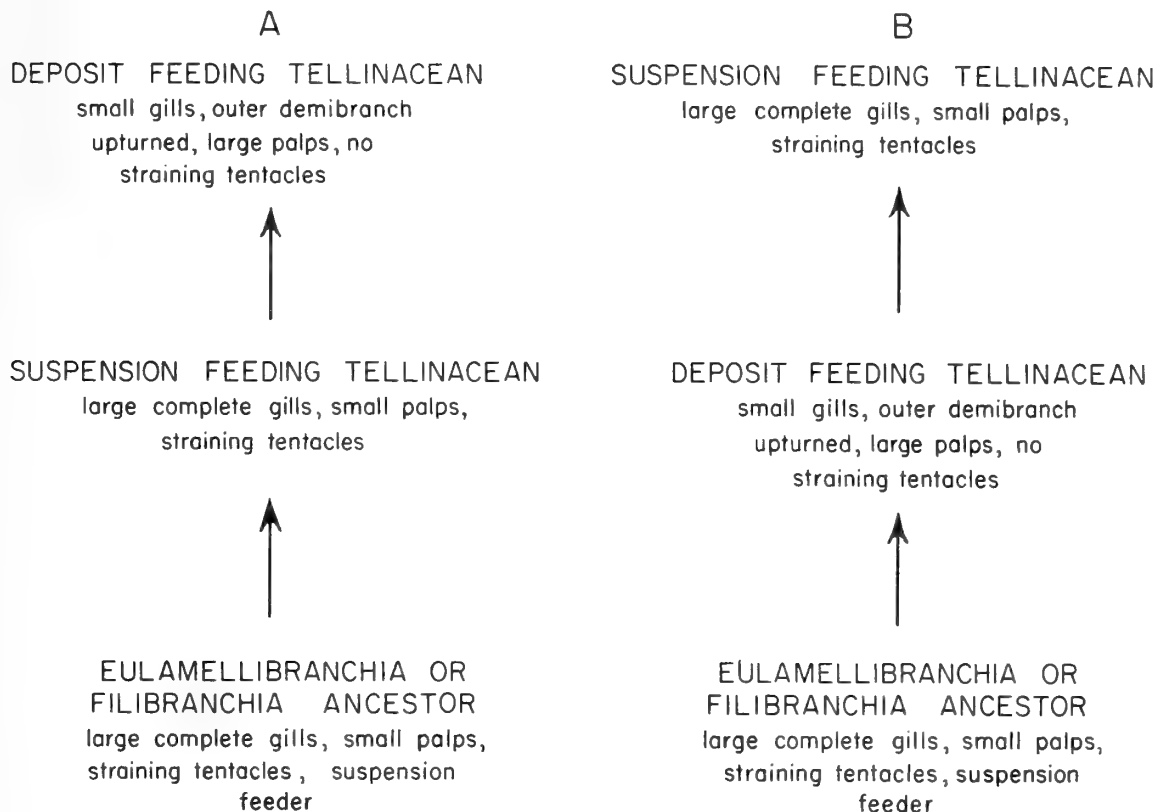


Figure 5

Two Possibilities for the Evolution of the Tellinacea.

has straining tentacles on the inhalant siphon. The ctenidia are complete, both demibranchs being large. In many Tellinacea the outer demibranch is upturned and reduced in size, a condition that prevents clogging (YONGE, 1949). Another feature of *D. gouldi* is that the ctenidia are large and the labial palps small. In deposit-feeding Tellinacea, such as *Macoma secta* (CONRAD, 1837) and *M. nasuta* (CONRAD, 1837) the opposite condition is true, and YONGE (*op. cit.*) states that this is correlated with the type of substratum. That is, where the deposits are firm the ctenidia are large and the palps small. The opposite condition occurs where the deposits are loose. This generalization does not appear to be true because *D. gouldi* is found on sand that is as loose as that found in the habitats of *M. secta*, and their gill and palp size-relationships are just the opposite from one another. It appears that in the case of *D. gouldi* the large gill and small palp is associated with suspension feeding.

The Tellinacea may have arisen from a suspension-feeding Filibranchia (YONGE, 1949, p. 72) or Eulamellibranchia stock (STASEK, 1963) and show progressive adaptations to deposit feeding. If this is so, a case can be made for *Donax* being an unspecialized or transitional type of tellinacean. An early tellinacean may have been a form with separate siphons bearing some straining device on the inhalant opening, two complete ctenidia, large gills and small palps, the approximate condition of some extant species of *Donax*. This type of organism would then give rise to a deposit-feeding tellinacean as shown in Figure 5A. It is difficult genetically to postulate that a suspension-feeding organism with two complete large ctenidia and probably with small palps gave rise to primitive Tellinacea that were deposit-feeders with upturned outer demibranchs and that lacked siphonal tentacles, and had large gills and small palps. This type of organism would then give rise to a suspension-feeding type such as *Donax* with two complete ctenidia, siphonal tentacles, large gills and small palps as shown in Figure 5B. This type of evolution necessitates that the morphology of a suspension-feeder was present in an ancestral tellinacean, then lost in the deposit-feeding Tellinacea, and then is regained in the suspension-feeding Tellinacea.

It is possible that *Donax* may possess certain neotenous characteristics as well as some primitive ones. A feature that could be equated with a primitive or neotenous condition is the stomach which is of Type IV, a condition that PURCHON (1960) regards as ancestral or simplified. In the other Tellinacea it is Type V, which is more advanced. Also, the gill and palp association of the Donacidae and Tellinidae is of Type III which STASEK (1963) interprets as neotenous.

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California Late Miocene Records of *Swiftopecten* HERTLEIN, 1935

(Pelecypoda : Pectinidae)

BY

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(Plate 47)

UNTIL RECENTLY (STANTON, 1966), the lowest recorded West Coast occurrences of species of the pectinid genus *Swiftopecten* HERTLEIN, 1935, were from Middle to Upper Pliocene strata (ANDERSON, 1905; ARNOLD, 1906; NOMLAND, 1917; DALL, 1898, 1907). In fact, the genus was generally regarded as an index to the Pliocene (VEDDER, 1960, p. B 327).

As a result of detailed collecting in the Castaic Formation (Late Miocene) of Los Angeles County, California, STANTON (1966, p 27) discovered the oldest record of the genus, thus lowering the known range to the Late Miocene. Recently, while undertaking a detailed biostratigraphic study of the Neogene Formations of the Coalinga Region, California, the writer collected one almost complete specimen (Plate 47, Figures 1 and 2) and a fragment of the hinge area of another specimen belonging to this genus from the Late Miocene Santa Margarita Formation (Univ. Calif. Mus. Paleo. locality D-1088), exposed on Coalinga Anticline, about 9 miles north of Coalinga, California. These records unequivocally show that the genus *Swiftopecten* was already established along the Eastern Pacific during Late Miocene times.

The genus *Swiftopecten* probably evolved in the Western Pacific. The probable ancestral form, *Nanaochlamys kitamurai* (KOTAKA, 1955) (see MASUDA, 1962, p. 128) was common in Japan in beds as old as Late Oligocene. Younger forms representing successive stages of evolution, such as *Nanaochlamys notoensis* (YOKOYAMA, 1929) and *N. notoensis otutumiensis* (NOMURA & HATAI, 1937) (MASUDA, *loc. cit.*) also ranged to Middle or Late Miocene. The oldest Japanese record of the type species, *Swiftopecten swiftii* (BERNARDI, 1858) (the single survivor of the genus) is Middle Miocene (MASUDA, 1959; 1962, p. 196; UOZUMI, FUJIE & MATSUI, 1966). It, therefore, appears reasonable to assume that the western North American representatives of the genus were derived from Miocene immigrants from the Western Pacific.

STANTON (1966, *loc. cit.*) collected two fragmentary specimens from the Castaic Formation (Calif. Inst. of Tech. locality 1663). These were medium-sized, thin-shelled individuals, about 50 mm high. The sculpture, which was reflected internally, consisted of a few low, broad ribs and furrows on which other smaller, finer riblets were superposed. About 3 riblets were present on

each major rib and 4 in each furrow. The flattish topped ribs were much wider than the intervening furrows, and there were no prominent constrictions on the shells. Though STANTON (*loc. cit.*) referred his specimens to *Chlamys parmeleei* (DALL, 1898) (a species commonly considered diagnostic of the Pliocene of Southern California; see VEDDER, 1960, *loc. cit.*), he noted that the sculpture differed from that of the type of DALL's species, but more closely resembled that of a specimen from the Pliocene of Crescent City, California, referred to DALL's species and figured by ARNOLD (1906, pl. 41, fig. 5). There is probably no doubt that the affinities of the Castaic specimens were with the Southern California species, *Swiftopecten parmeleei* (DALL).

The specimens collected by the writer from the Santa Margarita Formation of the Coalinga region (Figures 1 and 2) were unlike any previously described northeastern Pacific species. They were medium-sized, thin-walled and sub-circular; they were ornamented by 5 very prominent but narrow major ribs between which were other minor ribs of about the same width as the 5 major ribs. Two minor ribs were present in the interspaces between adjacent major ribs. Between, and superimposed on the major and minor ribs were numerous finer riblets. In addition, the almost complete valve (Figures 1 and 2) showed a few successive prominent constrictions. The characters of this species are somewhat reminiscent of those of some Japanese species referred to *Chlamys cosibensis* (YOKOYAMA, 1911) by MASUDA (1959, 1962) on the one hand, and those of *Swiftopecten wattsi* (ARNOLD, 1906) and *S. nutteri* (ARNOLD, 1906) from the California Middle and Late Pliocene on the other.

The following fossil species were collected from the same locality in the Santa Margarita Formation as the *Swiftopecten* spec.

#### PELECYPODA

*Aequipecten raymondi* (CLARK, 1915)  
*Diplodonta harfordi* ANDERSON, 1905  
*Hinnites multirugosus crassiplicatus* (GALE, 1928)  
*Lyropecten crassicardo* (CONRAD, 1856)  
*L. crassicardo nomlandi* (HERTLEIN, 1931)  
*L. estrellanus* (CONRAD, 1856)  
*Macoma diabloensis* CLARK, 1915  
*Mya (Arenomya) dickersoni* CLARK, 1915  
*Ostrea titan titan* CONRAD, 1857  
*O. titan eucorrugata* HERTLEIN, 1934  
*Solen* sp. indet.

#### GASTROPODA

*Forreria carisaensis* (ANDERSON, 1905)

#### CIRRIPEDIA

*Balanus (Balanus) gregarius* (CONRAD, 1856)

#### PISCES

Fish vertebrae

The present records show that two distinct species of *Swiftopecten* were already present in western North America during the late Miocene.

In the light of these recent discoveries, it would be necessary not only to review the evolution and the biogeography of the genus but also the relationship of the California Pliocene and ?Pleistocene species to the probable ancestral stocks from the Western Pacific.

It appears probable that MASUDA's (1962, p. 128) suggestion that the western North American "Pliocene" species *Swiftopecten parmeleei* (DALL, 1898) and *S. kindlei* (DALL, 1907) descended from *S. swiftii* s. s. may be oversimplified. The writer's contention is based on the facts that *Chlamys cosibensis* (YOKOYAMA, 1911) had no place in MASUDA's evolutionary scheme for *Swiftopecten*; and MASUDA failed to consider the Middle to Late Pliocene species *S. ethegoi* (ANDERSON, 1905), *S. wattsi* (ARNOLD, 1906), and *S. nutteri* (ARNOLD, 1906) from Middle California as members of the genus despite the very close similarity between the latter and the other northeastern Pacific fossil species.

The evidence presently at hand seems to suggest that *Swiftopecten swiftii*, and the northeastern Pacific species, *S. parmeleei*, *S. kindlei*, and possibly *S. ethegoi* evolved independently from a *Nanaochlamys*-like ancestor; whereas the other northeastern Pacific species such as the Santa Margarita form reported here, *S. wattsi* (ARNOLD) and *S. nutteri* (ARNOLD) evolved from the same stock as the Japanese species referred to *Chlamys cosibensis* (YOKOYAMA, 1911) by MASUDA.

It is not unlikely that more careful sampling of marine Middle and Late Miocene strata on the West Coast of North America may lead to the recovery of still older specimens.



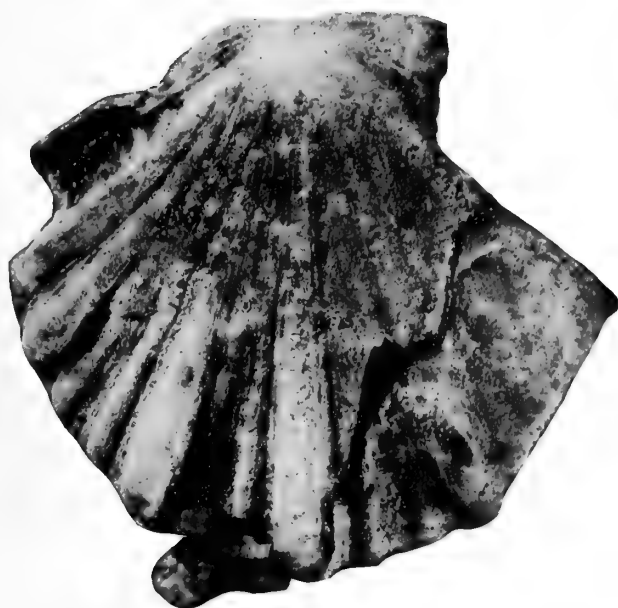


Figure 1



Figure 2

*Swiftopecten* spec.

Univ. Calif. Mus. Paleo. no. 36639, locality D-1088. Santa Margarita Formation, Coalinga Quadrangle, T. 19 S., R. 15 E., Sec. 28: 3630 feet north, 500 feet east. From Oyster and Pecten-bearing bed outcropping on the hill slope about 120 feet north of Standard Oil Well 184. Fossil bed is about 40 feet stratigraphically

Figure 1: Dorsal view of valve. (x 2)

below the base of the overlying Etchegoin Formation.

Figure 2: Dorso-lateral view of the same specimen showing two prominent constrictions on the ventral margin of the valve. (x 2)



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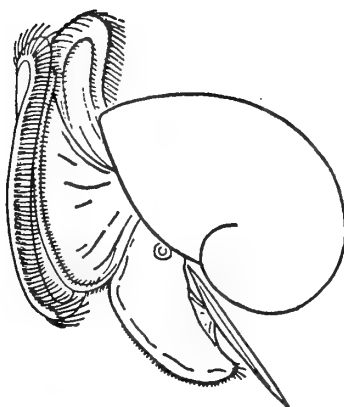
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## Notes on the Opisthobranchia of Baja California, Mexico, with Range Extensions - II

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(1 Text figure)

THE MAIN OBJECTIVE of this paper is to report range extensions for 16 species of opisthobranchs which have been collected in Baja California and in the Gulf of California, Mexico. The specimens reported are in the personal collection of the author. Included in this report are a few comments concerning the habitats, which I observed, of several species mentioned throughout the paper.

Collections were made at the following locations:

### Pacific Coast of Baja California:

Rosarito Beach	32° 27' N	117° 07' W
Santo Tomas	31° 32' N	116° 40' W
Eight miles south of Cape Colnett	30° 55' N	116° 14' W
Cape San Quintin (W side)	30° 22' N	116° 00' W
Old Mill in Bahia San Quintin	30° 29' N	115° 59' W
Bahia de Sebastian Vizcaino	28° 00' N	114° 30' W

### Gulf of California, Mainland Side:

Santa Cruz, Nayarit	21° 26' N	105° 17' W
Isla Venados, Mazatlan	23° 13' N	106° 29' W
One mile S of Puerto Peñasco	31° 18' N	113° 34' W

### Gulf of California, Baja California Side:

Isla Cerralvo	24° 10' N	109° 52' W
Isla Las Animas	25° 06' N	110° 31' W
SW end, Isla S. Lorenzo Sur	28° 41' N	112° 55' W
2.8 mi S of Puertocitos	30° 25' N	114° 40' W

Comments on habitats: The area about 8 miles south of Cape Colnett is rocky with several large shallow tide pools. The rocks for the most part are not of sandstone or mudstone but of hard rounded igneous rock. The lower portions of these rocks are buried in the sandy substrate allowing no adequate habitat for sponges, hydroids, or bryozoans, but provide an ideal habitat for chitons. The combination of round rocks partly buried in the sand makes for poor nudibranch browsing and col-

lecting. On 26 May, 1963, during a low tide, I found nudibranchs moving about the surface-film of the tide pools. This seems to afford the most productive way of collecting nudibranchs in the Cape Colnett area.

Collecting opisthobranchs in the rocky areas along the west side of Cape San Quintin seems to be worth the effort. There are several areas with an abundance of algae where the rocks are suitable for opisthobranch collecting. Many more species of opisthobranchs will undoubtedly turn up in this area.

The inner bay of San Quintin offers several habitats suitable for opisthobranchs. The iron pilings of a pier about a mile south of the Old Mill support a large mass of sponges, hydroids, oysters and other marine organisms commonly found in bays. The narrow opening in the Old Mill dike in the inner part of the bay creates swift currents during tidal changes. Here vast amounts of oysters, clumps of hydroids and ostrich plume hydroids, *Aglaophenia* sp. abound. Two *Aphysia californica* were seen in these upper reaches of the bay. Several species of nudibranchs were found here. Because of the swift current, the plant and animal life at the dike strongly suggested the habitat of an outer coast rather than that of a bay. *Flabellina*, an offshore nudibranch, was found here.

My thanks go to Clinton Collier, Keith Radford, Carol Bumgardner, Fay Wolfson, Edward Wilson, Allen Sloan, George Hanselman and John Souder for collecting some of the nudibranchs discussed below. I wish to thank also Richard Banks and Joan Steinberg for reading the manuscript and for making valuable suggestions.

### Species Listed

In some cases the new range of a species is enclosed in brackets [ ], followed by the formerly known range in parentheses ( ). Some ranges previously listed for some

species included in the following list may be found in LANCE, 1961, 1966, and FARMER & COLLIER, 1963.

*Elysia hedgpethi* MARCUS, 1961

More than 100 animals were seen on 31 December, 1963, along with their nidosomes on the green alga *Codium* in Bahia San Quintin. This extends the range south from La Jolla, tending to close the disjunct range between the Pacific coast and the Gulf of California of specimens reported by LANCE (1966, p. 71: Bahia de los Angeles, Gulf of California).

*Aplysia vaccaria* WINKLER, 1955

The animal from Cape Colnett was 290 mm long when actively crawling. It was very dark reddish brown or nearly black with white speckled patches over the entire body except for the bluish blackish-brown foot. The tail was distinctly short and rounded. When disturbed the head and tail pulled into the body and virtually disappeared. The animal did not secrete a fluid when disturbed, but small white flecks of a fluid-like substance were given off. On 10 February 1964 it laid a large pinkish-white egg mass in my aquarium, about a month after having been caught. [San Pedro, California to 8 mi S of Cape Colnett.] (San Pedro to Point Loma, California).

*Stylocheilus longicauda* (QUOY & GAIMARD, 1824)

Thirty-one animals were collected from hundreds seen in a low tide pool near Puertocitos on 1 December, 1963. The animals were congregated in groups of from 30 to 50 on or near rocks or in many instances crawling from one

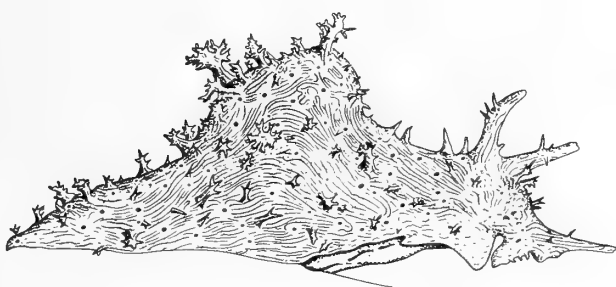


Figure 1

*Stylocheilus longicauda* (QUOY & GAIMARD, 1824)

place to another in a follow-the-leader fashion. They seemed to follow the same slime trails which formed roadways with intersections on the bottom of the pool. The animals were first seen during the evening low tide

and were also seen there during the morning low tide. KAY, 1964, reported that *Stylocheilus longicauda* is circum-tropical, describing animals from the tropical western Atlantic as well as from the east coast of Africa. BABA (1955) described it as being circum-equatorial in the Atlantic, Red Sea, Indian Ocean and in the Pacific ranging from Riûkiû to Japan. KAY (*op. cit.*) reported it from Hawaii. I have collected specimens from Isla Cerralvo (Figure 1) in the southern end of the Gulf of California in late May, 1962, and just north of Puertocitos in the upper end of the Gulf of California.

*Glossodoris californiensis* (BERGH, 1879)

Animals have been found at Isla las Animas, June, 1964; at Santa Cruz, Nayarit, 22 December, 1965; and at Puerto Peñasco, 5 February, 1966. LANCE (1966, p. 72) gives localities where this species has been collected in the upper Gulf. These new records pertain to material from a few southern Gulf localities and from the west coast of the Mexican mainland in the upper part of the Gulf.

*Chromodoris banksi* FARMER, 1963

Three specimens were collected on a rocky reef 1 mile S of Puerto Peñasco, Sonora, in February, 1966. Previous localities are: 2.3 miles S of Puertocitos; Bahia San Luis Gonzaga; Puerto Refugio at the N-end of Isla Angel de la Guarda (FARMER, 1963).

*Discodoris heathi* MACFARLAND, 1905

Fifteen animals were collected at Santo Tomas on 25 May, 1963. The largest was 35 mm long. One specimen was collected at the Old Mill in Bahia San Quintin on 29 November, 1963. [Vancouver Island to Bahia San Quintin.]. (Vancouver Island to Ensenada.)

*Triopha grandis* MACFARLAND, 1905

One animal, 9 mm long when actively crawling, was collected at Cape San Quintin. It was orange with a faint brownish wash. The body had tubercles that were light colored, but not bluish. The specimen was collected on 30 December, 1963. [Santa Cruz, Santa Clara County, California, to Cape San Quintin.] (Santa Cruz to Laguna Beach, California.)

*Aegires albopunctatus* MACFARLAND, 1905

A small animal was seen (but not collected) about rocks on the outer coast of Cape San Quintin on 30 December, 1963, extending the range of the species south from Ensenada. LANCE (1966, p.75-76) points out that it has been observed in the Gulf of California at Puerto Refugio and Bahia de los Angeles.

*Acanthodoris lutea* MACFARLAND, 1925

The animal was crawling about the bottom of a tide pool S of Cape Colnett when found on 26 May, 1963. [Dillon Beach, California to 8 mi S of Cape Colnett.] (Dillon Beach to Point Loma, California.)

*Onchidoris hystricina* (BERGH, 1878)

Animals have been collected at Santo Tomas in rocky tide pools and near Cape Colnett in a similar habitat, on 25 May, 1963. Animals collected were, for the most part, under the surface film of tide pools. [Alaska to 8 mi S of Cape Colnett.] (Alaska to Point Loma, California.)

*Dirona picta* MACFARLAND in COCKERELL & ELIOT, 1905

A large animal was collected on a rocky reef at low tide 1 mi S of Puerto Peñasco, Sonora, Mexico on 5 February, 1966. This is the first record of the species on the east side of the Gulf. (Dillon Beach, California, to Puerto Rompiente; Puertocitos.)

*Antiopella barbarensis* (COOPER, 1863)

Fifteen animals were collected at the Old Mill in Bahia San Quintin. Most were found among large numbers of ostrich plume hydroids; one was found on mud. All were obtained on 30 November and 31 December, 1963, in this area. [Santa Barbara, California, to Bahia San Quintin.] (Santa Barbara to Point Loma, California.)

*Flabellina iodinea* (COOPER, 1862)

Ten specimens were taken at Cape San Quintin on 2 December, 1963, apparently washed into the intertidal area. One other was taken at the Old Mill dike in the upper reaches of Bahia San Quintin on 29 November, 1963. Another two were taken in about 50 feet of water off Isla San Lorenzo on 22 October, 1964. [Vancouver Island to Cape San Quintin; SW end of Isla San Lorenzo, Baja California.] (Vancouver Island to the Coronados Islands.)

*Coryphella cooperi* COCKERELL, 1901

The species was fairly common in the base of clumped hydroids in a particularly swift current at the Old Mill dike in Bahia San Quintin on 31 December, 1963. [San Pedro, California, to Bahia San Quintin.] (San Pedro, California.)

*Catriona lagunae* O'DONOGHUE, 1926

Two specimens were collected intertidally at Rosarito Beach on ostrich plume hydroids growing on *Gelidium* in the low tide-level tide pools on 27 January, 1963. One animal was 7 mm long, the other was 5 mm long. [Point Pinos, Monterey Bay, California, to Rosarito Beach.] (Monterey Bay to Point Cabrillo, California.)

*Armina californica* (COOPER, 1862)

Two specimens were collected at Puertocitos on 5 February, 1966. They were in the water on sandy mud at the edge of an algae-covered rock below the usual low-tide level. MACFARLAND (1966, p. 203) states that the species had been taken as far south as the Bay of Panama, from the lower west coast of the Gulf of California, California coast, Oregon coast and from the Vancouver Island region. I have taken the species from Bahia de Sebastian Vizcaino in deep water on 8 August, 1952. The animals from Puertocitos establish the species from the upper part of the Gulf of California.

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# The Suppression of Autotomy in *Linckia multifora* (LAMARCK) by a Parasitic Gastropod, *Stylifer linckiae* SARASIN

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(Plate 48; 1 Map)

## INTRODUCTION

HOST-PARASITE RELATIONSHIPS in which the parasite in some way interferes with the normal growth processes of the host have been known for many years. Indeed, aside from those reports concerning the more obvious pathological or lethal manifestations of parasitism, much of the literature related to the responses of host organisms has been devoted to this topic. As examples of this sort of host-parasite interaction might be mentioned such diverse phenomena as the stunting or retardation of growth and development seen in many organisms, including man, when infected by any one of a wide variety of parasites (summarized by VON BRAND, 1952); parasitic castration and inhibition of molting in crustaceans infected with rhizocephalans or epicarideans (reviewed by REINHARD, 1956); gigantism in snails harboring trematode larvae (ROTHSCHILD & ROTHSCCHILD, 1939; PAN, 1962); the accelerated pupation of insect larvae infected with parasitic insects (reviewed by VARLEY & BUTLER, 1933); and the enhanced growth (as increase in weight) of laboratory mice experimentally infected with the pleurocercoid larvae of a cestode (MUELLER, 1963).

The present report deals with the occurrence of a similar phenomenon in a sea star, *Linckia multifora*, when it is infected with *Stylifer linckiae*, a parasitic gastropod. More specifically, observations are reported which indicate that the tendency for "spontaneous" autotomy, normally quite high in *L. multifora*, is considerably reduced in parasitized rays, and it is suggested that this reduction is caused by the parasite.

## MATERIALS AND METHODS

Specimens of *Linckia multifora* were collected in Kaneohe Bay, Oahu, Hawaii. In the laboratory, all animals were maintained in running sea water, in 35-gallon aquaria. In the earlier phases of this study wooden aquaria were used, but these were replaced by fiberglass aquaria during the experimental portion of the investigation.

In the initial observations both parasitized and normal animals were placed in the same aquaria, where they were maintained for periods of up to one month. All animals were examined at least once each day. Animals having autotomized one or more rays, the autotomized rays, and any animal appearing moribund<sup>3</sup> were removed from the aquaria as soon as they were discovered. All autotomized rays were examined carefully for the presence of *Stylifer linckiae* at the time of their removal. Records were kept of the number of animals autotomizing one or more rays and of the number of parasitized rays autotomized.

Autotomy was induced experimentally by ligating rays near their base. Ligatures, for which either silk thread (Experiment I) or fine copper wire (Experiment II) was used, were applied to two rays on each animal. Thus, normal animals had two uninfected rays ligated, and parasitized animals had ligatures on either one uninfected and one infected ray, or on two infected rays. These animals were then placed in a fiberglass aquarium in

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<sup>3</sup> The condition of *Linckia multifora* is readily determined by brief examination. If several patches are present on the rays adjacent to the ambulacra, where the epidermis has been lost and the underlying ossicles are plainly visible, it is usually an indication that the animal is in poor condition and will eventually disintegrate entirely.

running sea water and maintained without food for 10 days. During this time, periodic examinations were made, and the occurrence of autotomy in normal and in parasitized rays recorded. Autotomized rays were discarded as soon as they were detected.

## RESULTS

### A. Frequency of Infection and General Morphology of *Stylifer linckiae*

A total of 665 specimens of *Linckia multifora* was examined for the presence of *Stylifer linckiae*. Fifty-four of these animals, or 8.1%, were parasitized. Of these, 49 had one infected ray and 5 had two infected rays. Collections were made from two different locations, however, and the frequency of infection in these two populations of *L. multifora* differed considerably (Table 1).

Table 1

Number of <i>Linckia multifora</i> infected by <i>Stylifer linckiae</i> according to Location of Collecting Site			
Population Designation	Number of Animals Collected	Number of Animals Parasitized	Percent
B-8	525	53	10.1
S. I.	140	1	0.7

The locations of the collecting sites are shown on the map in Figure 1.

This difference, the cause of which is unknown, is mentioned primarily because all laboratory observations were made on animals from the population designated as B-8, and the higher frequency of infection in this population was used in the statistical analysis of the data.

The external appearance of *Linckia multifora* parasitized by *Stylifer linckiae* is shown in Plate 48, Figure 1. The snails are usually found in enlarged areas or "galls" on the adoral, lateral or aboral surface of the rays, where they occupy a position within the body wall but separated from the coelomic cavity by a layer of connective tissue (Plate 48, Figure 2). The capsule-like gall remains open to the exterior by means of a small pore which, according to HIRASE (1932), allows the snail to maintain a flow of water into and out of the gall for respiration and the removal of waste material. A single gall may contain from one to several snails (up to 5 in the present study). Internally, however, each individual snail is encapsulated by a separate connective tissue layer (Plate 48, Figure 3).

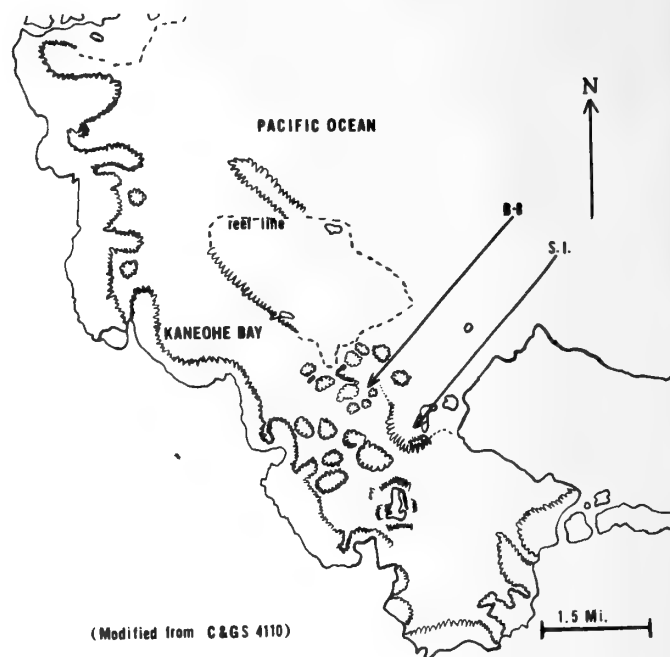


Figure 1  
Map of Kaneohe Bay, Showing Location of *Linckia multifora* Collecting Sites

### B. Frequency of Autotomy

The loss of rays in various species of Asteroidea by what has been termed "spontaneous" autotomy has been known for many years (HAECKEL, 1878; HIROTA, 1895; KELLOGG, 1904). Although the spontaneity of this process may be doubted, nothing is known of the actual stimuli involved in initiating this so-called spontaneous autotomy, nor is there any information available on the underlying physiological factors.

Autotomous loss of rays is quite prevalent in the family Linckiidae, although different species apparently vary somewhat in the extent to which it occurs. For example, EDMONDSON (1935) reported that 44.7% of the specimens of *Linckia multifora* collected by him showed signs of having autotomized at least one ray at some time in the past. Specimens of *L. guildingii*, however, were reported to show no indications of autotomy, although they were collected in the same area and at the same time as was *L. multifora*.

In the present study it was found that approximately 60% of the animals brought in from the field and maintained in wooden aquaria autotomized at least one ray (263 of 436). This frequency is almost twice as high as



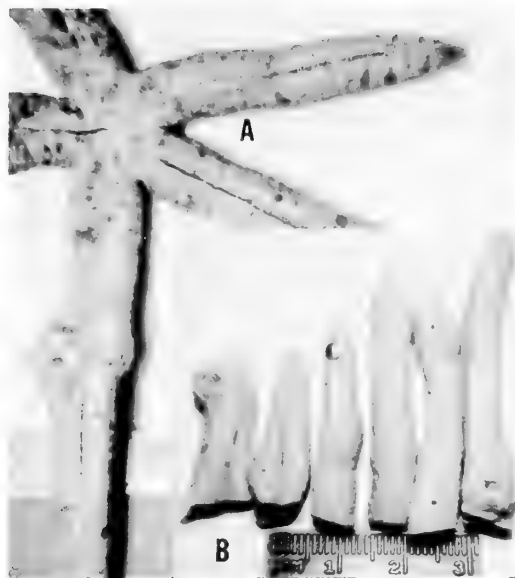


Figure 1



Figure 2

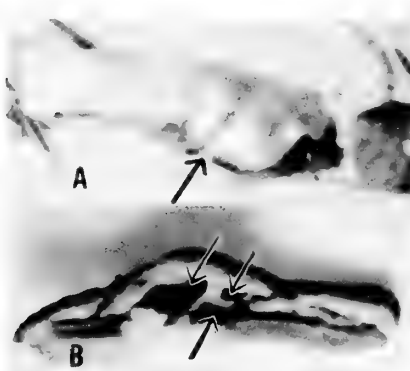


Figure 3

Figure 1 a: Oral view of *Linckia multifora*, showing the external appearance of the gall formed by *Stylifer linckiae*.

Figure 1 b: A series of parasitized rays from different individuals, selected to demonstrate the variability in size and location of the galls.

Figure 2: Partially dissected ray of *Linckia multifora*. The arrow indicates the layer of tissue separating *Stylifer linckiae* from the coelomic cavity of its host.

Figure 3 a: Partially dissected ray infected with two *Stylifer linckiae*. The arrow indicates the layer of host tissue separating the parasites.

Figure 3 b: Partially dissected ray which previously contained three *Stylifer linckiae*. The snails have been removed to show the distinct partitions which form three separate capsules.



the 36% (18 of 50) observed by EDMONDSON (op. cit.) under similar conditions. The cause of this high frequency of autotomy is unknown, although it was observed subsequently that when animals were kept in plexiglass aquaria the frequency of spontaneous autotomy was only 37.5% (24 of 64), which suggests that the nature of the aquaria might have been responsible.

### C. Autotomy of Parasitized Rays

If it is assumed that autotomy of rays in *Linckia multifora* and parasitization of rays by *Stylifer linckiae* are independent of one another, and that spontaneous autotomy is a random event that does not favor any particular ray, one would expect to find that a certain number of parasitized rays would be autotomized, with the actual frequency in any given situation depending upon the frequency of autotomy and the level of infection. Observations made during the early phases of the investigation, however, indicated that parasitized rays were not autotomized as readily as were normal rays and that, in fact, the two events were not independent. This was suggested by the fact that only one out of a total of 58 parasitized rays was autotomized. To confirm this observation, it was hypothesized that autotomy and parasitization were independent events, and this hypothesis was then tested by the Chi Square method. The results of this analysis are shown in Table 2.

The difference between the observed and expected frequencies was found to be significant ( $\alpha = 0.025$ ), which supports the original conclusion that autotomy of rays in *Linckia multifora* is not independent of parasitization by *Stylifer linckiae*.

Table 2

Expected <sup>4</sup> and Observed Frequencies of Autotomy and Parasitization		
Condition of Rays	Frequency of Occurrence	
	Observed	Expected
Normal rays autotomized	286	280.34
Normal rays not autotomized	2156	2161.66
Parasitized rays autotomized	1	6.66
Parasitized rays not autotomized	57	51.34
Total number of rays	2500	-

$$\chi^2 = 5.824; df = 1$$

<sup>4</sup> Expected frequency assuming independence of autotomy and parasitization

To substantiate the results of the statistical analysis, an attempt was made to obtain more conclusive evidence by experimentally inducing autotomy in normal and parasitized rays. Autotomy was induced by tightly ligating the rays near the base, a method found effective in previous investigations (EDMONDSON, op. cit.). Table 3 shows the results of these experiments.

Although autotomy occurred in parasitized rays, the frequency of its occurrence was significantly lower ( $p < 0.01$ ) than that of normal rays. These results lend further support to the conclusion that autotomy is inhibited in parasitized rays.

Table 3

Autotomy of Ligated Rays			
Condition of Rays	Number of Rays		Percent
	Ligated	Autotomized	Autotomy
Normal			
Experiment I	32	21	65.6
Experiment II	29	14	48.3
Total	61	35	57.4
Parasitized			
Experiment I	12	4	33.3
Experiment II	15	4	26.7
Total	27	8	29.6

## DISCUSSION

Although nothing is known of the actual causes producing the reduced frequency of autotomy in parasitized rays, the most obvious explanation would be that the snail in some way inhibits its occurrence. Despite its speculative nature, such a conclusion is not entirely unwarranted, especially if one considers the frequent occurrence of similar phenomena in other parasitized organisms (see Introduction).

In the usual type of host-parasite interaction in which the normal growth processes of the host are altered, the changes that occur frequently can be attributed to such direct factors as a decrease (or increase) in the supply of nutrients needed for growth, or to some cytological or histological damage inflicted by the parasite. There are several reasons for believing that the present case does not belong to this category. For one, when not "spontaneous," autotomy usually is considered to be caused by an injury,

by some noxious stimulus, or by unfavorable environmental conditions, and it is just this response that appears to be blocked. Furthermore, in 3 of the 8 parasitized rays autotomized in the ligation experiments, the ligatures were located immediately adjacent to a gall. If autotomy were being inhibited by some structural damage or mechanical interference caused by the snail, these circumstances should have produced the strongest inhibitory effects, and if any parasitized rays were lost, one would expect it to be those on which the ligations were further away from the gall.

A very tempting explanation of these results is that *Stylifer linckiae* is interfering directly with some mechanism by which autotomy is normally controlled. It is also tempting to consider that the normal control mechanism is endocrinological in nature, and that what is occurring is similar to the parasite-induced alterations in the endocrine control of secondary sex characters associated with parasitic castration in crustacea (REINHARD, op. cit.). Such a mechanism could account for the fact that ligatures applied at considerable distances from the site of infection failed to produce autotomy. The major objection to such speculation, however, is that absolutely nothing is known of the normal mechanisms of autotomy. In fact, one of the most exciting prospects emerging from this study is that the parasite-induced suppression of autotomy may provide a tool for the investigation of the events normally associated with this process.

Another interesting aspect of the suppressed frequency of autotomy concerns its possible adaptive significance for the snail. The available evidence, although not conclusive, suggests that this phenomenon might be of considerable survival value to *Stylifer linckiae*. This is indicated by observations made on the survival of isolated rays and snails. First, it is apparent that although autotomy may be of common occurrence in *Linckia multifora*, the survival of autotomized rays is extremely low. In one experiment, for example, 64 autotomized rays were isolated in a separate aquarium in order to study the regeneration of the proximal portions. At the end of three weeks, however, only 15 of these rays were still alive. In another experiment, 60 isolated rays were observed. After two weeks, only two remained alive. Similar findings have been reported by EDMONDSON (op. cit.), although no actual data are given in his paper.

Secondly, from the results of preliminary studies it appears that the survival rate of *Stylifer linckiae* when removed from the rays of *Linckia multifora* is very low also. Thus far observations have been made on a total of only 14 animals, however, and while none of these animals survived for over 48 hours following their isolation, fur-

ther investigation involving a larger number of animals would be desirable.

Nevertheless, the results of these preliminary studies indicate a low rate of survival for *Stylifer linckiae* when it is outside the host. In light of this, the significance of its ability to prevent the autotomy of the ray in which it is located is immediately evident, since the chances also are very slight that the ray will survive and continue to provide the snail with conditions suitable for its existence. Furthermore, free-living specimens of *S. linckiae* have never been reported, exactly as one would expect if this species were incapable of existence independent of its echinoderm host.

### ACKNOWLEDGMENTS

I would like to thank Dr. E. A. Kay for assistance in the identification of *Stylifer linckiae*, and Drs. C. H. Hand and E. S. Reese for their critical review of the manuscript.

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## Habitat Preferences of *Littorina sitkana* on Two Shores of Differing Exposure in Alaska

BY

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DURING THE SUMMER of 1963 an extensive investigation of the intertidal ecology of the shores of Three Saints Bay, Kodiak Island, Alaska, was undertaken by the author, an area which was subsequently submerged about 3.0 feet in the Alaskan Earthquake of March 27, 1964. In the course of this investigation, the greater part of which will be reported elsewhere, several aspects of the ecology of the common shore mollusks were revealed and one is reported here.

Three Saints Bay lies on the southeast coast of Kodiak Island about 60 miles from the city of Kodiak. The bay is in the shape of an "T", and is ringed with steep sided mountains which rise, in most areas, abruptly from the bay. Almost all intertidal areas are solid rock, boulders or cobble. There are no true muddy shores.

The two shores under consideration here lie on opposite sides of the bay, one on the west shore and the other on the east shore. The beach on the west side of the bay, designated as the Beach Transect Area, was well protected from any wave action in the bay proper by a peninsula of land which curved around in front of the sampling area cutting it off from the mouth of the bay and leaving a wide opening to the bay proper only in the direction of the head of the bay. As a result of the existence of the peninsula, a quiet water lagoon was formed fronting the sampling area.

The sampling area on the east side of the bay, designated as the East Reef, was on the exposed side of a peninsula which extended out into the bay and faced the mouth of the bay and the incoming sea swell, although wave action was never severe due to its location a mile up the bay from the mouth.

The substrate of the Beach Transect Area was coarse gravel or cobble except at the lowest levels of the tidal zone where a flat area of sandy-mud occurred.

The substrate of the East Reef was similar except that the area also had numerous large (12 - 16 inches) rocks dotting the surface or imbedded in the surface pavement of cobble.

Both of these sample areas were very sharply zoned into three bands, and these zones and their major components were the same on both areas. The lowest zone of each reef was green in color and entirely dominated by eelgrass (*Zostera marina* LINNAEUS, 1758). The middle zone was a dark brown color due to the presence of large amounts of the alga *Fucus distichus*. The highest zone was black in color, due to the exposed bare cobble and rocks, interrupted by patches of white which indicated the presence of numerous barnacles (mainly *Balanus cariosus* (PALLAS, 1788)). This zone was completely devoid of macroscopic algae. These zones were named Eelgrass, Fucus, and Barnacle respectively.

The two areas were sampled by different methods, and hence are not directly comparable. However, the results are so dramatic that it is felt that the differences are not an artifact of the sampling methods, but represent a true picture of conditions. The Beach Transect Area was sampled by 5 belt transects of contiguous 0.25 m<sup>2</sup> quadrats running from low water to the level reached by the highest tides. In all, 286 quadrats were taken and 22570 *Littorina sitkana* PHILIPPI, 1846, individuals were counted.

The East Reef was sampled by 55 0.25 m<sup>2</sup> quadrats which were chosen at random from a grid set out over the entire area. A total of 2661 *Littorina sitkana* were counted.

*Littorina sitkana* was a prominent member of the fauna of both the sampling areas. However, analysis of the quadrats by individual zones in which they had been taken revealed a dramatic unexpected change in habitat for *L. sitkana* in the two areas (Table 1).

Although *Littorina sitkana* had been found almost exclusively in the *Fucus* zone of the Beach Transect Area, not a single individual was found in this same zone in the East Reef (Table 1). It seems certain that had more quadrats been taken in the East Reef, at least some individuals of *L. sitkana* would have been found in the *Fucus* and Eelgrass zones, but the preponderance of individuals would still have been in the barnacle zone.

Table 1

Percentage of Total Number of Individuals of  
*Littorina sitkana* in Each Zone

Zone	Beach Transects <sup>1</sup>	East Reef <sup>2</sup>
Barnacle	4.7	100.0
Fucus	94.6	0.0
Eelgrass	0.7	0.0

<sup>1</sup> Total of 22570 individuals counted in 286  
 $\frac{1}{4}$  m<sup>2</sup> quadrats.

<sup>2</sup> Total of 2661 individuals counted in 55  
 $\frac{1}{4}$  m<sup>2</sup> quadrats.

Since the zones and organisms characterizing the zones were similar in both areas, this marked change of zone of occurrence of *Littorina sitkana* is most interesting and invites speculation as to its cause. One obvious explanation is that it is due to the differing exposure factors of each area, especially wave action. The possibility that this change is due to the presence of the large rocks on the one reef and not the other cannot be discounted here, but appears to be of lesser importance due to the observation that *L. sitkana* was not always associated with the large rocks on the East Reef, but was often found on the small cobble.

Another explanation of the change may be found in the differences in tide level of the zones on the two areas. On the Beach Transect Area the *Fucus* zone was found between + 0.5 feet and 4.5 feet (MTL) whereas on the East Reef the *Fucus* zone was a much narrower band

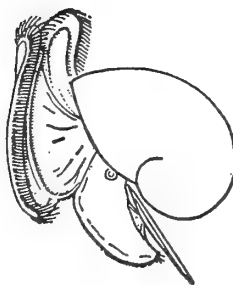
occurring only between 0.0 feet (MLLW) and + 1.8 feet. Hence, at least part of the Barnacle zone of the East Reef occurs at the same tidal levels as the upper part of the *Fucus* zone in the Beach Transect Area. Although this certainly offers a partial explanation of the disparity observed, it probably is not the only answer since closer analysis of the Beach Transect data for *Littorina sitkana* showed that the greatest densities occurred in the tidal range of + 1.0 to + 2.0 on the Beach Transect Area, precisely the level of the *Fucus* zone on the East Reef.

Perhaps all of the above factors enter into this situation, and it is not known which, if any, is of most importance.

Since *Littorina sitkana* is a common intertidal mollusk of the northern parts of the Pacific Coast of America (RICKETTS & CALVIN, 1939) and the genus has been considered as characteristic of certain levels of the shore (STEPHENSON & STEPHENSON, 1949), it is of interest here to report this marked change of habitat between two shores which are, in most respects, quite similar. Results obtained in this study would seem to indicate that *L. sitkana* cannot be used as an indicator species for a single zone, at least in Alaska, and that relatively small differences may alter markedly its distribution on a shore.

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## West American Species of *Lucapinella*

BY

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(Plate 49; 3 Text figures)

THE WEST AMERICAN SPECIES of *Lucapinella* are at present confused in the literature. Panamic specimens previously identified as *L. callomarginata* (DALL) belong to two separate species. One of these species, *L. milleri* BERRY, was described in 1959 but has remained unfigured. Another species misidentified as *L. callomarginata* is described herein. The four west American species are briefly characterized and new information on their distribution is offered.

### ACKNOWLEDGMENTS

The type material of the new species described herein was collected on an expedition aboard the yacht "Sea Quest," as a guest of Mr. and Mrs. Richard F. Dwyer, who have very generously made their vessel available for field work of the Museum.

Mr. Emery Chace arranged the loan of comparative material from the collection of the San Diego Museum of Natural History (SDNHM). Photographs were made by Museum photographer Mike Hatchimonji and radular drawings were prepared by Christiane Charpides. I am grateful to Dr. A. Myra Keen for criticism of the manuscript.

### *Lucapinella* PILSBRY, 1890

*Lucapinella* PILSBRY, 1890 (1888-1898), vol. 12, p. 179. - 1891 (1888-1898), vol. 12, p. 195. Type species, by SD of PILSBRY, 1890 (Dec.), p. 96: *Clypidella callomarginata* DALL, 1871.

**Diagnosis:** Shell elongate, anterior end narrow, fissure centrally located, oval or oblong. Sculpture of imbricating ribs; internal margin thickened, offset by a groove. Shell not covered by mantle margin but animal too large to be contained within the shell.

Radulae of 3 species of west American *Lucapinella* have been examined (Text figures 1 through 3). The

basic features of each species are similar. The central and four inner lateral teeth are broad, with straight cutting edges, and the outermost lateral is large and bears two cusps, a main cusp and a lateral cusp. A lateromarginal plate is present and the number of marginal teeth is large.

*Lucapinella* is known only from the warm temperate and tropical regions of North and South America, in the Eastern Pacific and Western Atlantic. *Lucapinella limatula* (REEVE, 1850) is the best known Caribbean species (WARMKE & ABBOTT, 1961, p. 38; pl. 6, fig. 9), but the status of other named forms cited in FARFANTE (1943) and USTICKE (1959) is not clear.

### Key to the West American Species of *Lucapinella*

1. Shell markedly narrow anteriorly ..... 2
- Shell with sides nearly parallel ..... 3
2. Fissure elongate, its length two times width  
..... *L. callomarginata*
- Fissure oval, its length one and one-half times width  
..... *L. eleanorae*
3. Fissure relatively large, one-fourth the length of  
the shell ..... *L. milleri*
- Fissure relatively small, more than one-fifth the  
shell length ..... *L. aequalis*

### *Lucapinella callomarginata* (DALL, 1871) ex CARPENTER MS

(Plate 49, Figures 1 and 2; Text figure 1)

*Clypidella callomarginata* DALL, 1871, p. 133, pl. 15, fig. 8  
*Lucapinella callomarginata* (DALL). - PILSBRY, 1890, p. 96. - 1891 (1888-1898), vol. 12, p. 196, pl. 44, figs. 3-5, pl. 61, figs. 1-5 [animal]. - DALL, 1909, p. 243. - KEEN, 1958, p. 250, fig. 29.

**Diagnosis:** Shell elongate, relatively large and thick, markedly narrow anteriorly, slopes straight or concave,

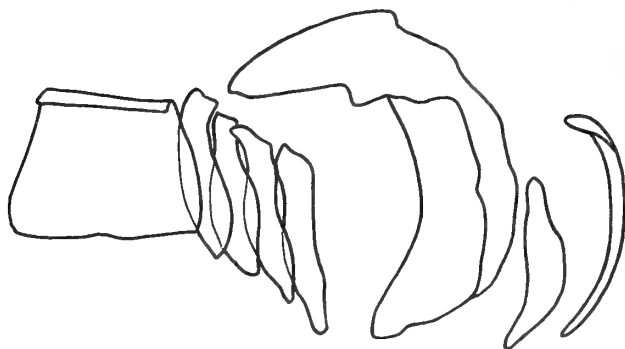


Figure 1

Radula of *Lucapinella callomarginata* (DALL)

Newport Bay, Orange County, California (LACM). Shown from left to right: rachidian tooth, four inner lateral teeth, the large fifth lateral tooth, the lateromarginal plate and the first of many marginal teeth.

posterior margin of shell slightly elevated. Foramen large, elongate, nearly central, sides of foramen elevated, forming the highest point of the shell. Sculpture of primary and secondary ribs, with tertiary ribs in mature specimens; concentric sculpture imbricate, raised on crossing major ribs. Color cream or buff with radiating bands of gray. Mature specimens with thick internal margin nearly obliterating the marginal crenulation. Muscle scar narrow, apertural callus narrow. Dimensions: long. 19, lat. 10, alt. 4.5 mm (holotype).

**Type Material:** Holotype, U. S. National Museum, cat. no. 19478 (Plate 49, Figures 1 and 2). Type locality: San Pedro, Los Angeles County, California.

**Distribution:** Morro Bay, California, to Magdalena Bay, Baja California. Records: Morro Bay, San Luis Obispo County, California (Dept. Zool., Univ. Calif. Berkeley collection); Magdalena Bay, Baja California (LACM; USNM no. 150847). Although the species has been reported from localities in northern California, no authentic specimens from north of Morro Bay have been examined. The species is not known in the Gulf of California or in the Panamic province proper. As suggested by KEEN (1958), records from the Panamic province undoubtedly apply to other species. DALL (1909) recorded the species from Chile but no specimens so labeled have been located in the U. S. National Museum. A record of *L. callomarginata* (DALL) from Puerto Rico given by FARFANTE (1946) is probably adventitious.

**Discussion:** *Lucapinella callomarginata* occurs on the undersides of rocks and on pilings near aggregations of

*Mytilus edulis* in bays and channels in southern California. It has not been collected in the sublittoral zone.

Variation of the shell is not extensive. Mature specimens tend to develop thickened shells with a heavy inner margin, obliterating the crenulations.

Only *Lucapinella eleanorae* is as markedly narrow anteriorly as *L. callomarginata*. *Lucapinella callomarginata* has a larger, thicker shell and more elongate foramen than the former.

*Lucapinella eleanorae* McLEAN, spec. nov.

(Plate 49, Figures 3 and 4; Text figure 2)

**Diagnosis:** Shell thin, markedly narrow anteriorly, elevation low, base of shell nearly flat. Posterior slope of shell concave. Foramen relatively small, oval, slightly anterior to center. Radial sculpture of approximately 20 primary ribs, 20 secondary ribs and 40 tertiary ribs appearing at later growth stages. Concentric sculpture forming imbrications with the radial ribs, producing short spines on crossing primary ribs. Color reddish buff with radiating bands of gray. Margin crenulated, mature specimens with broad, slightly thickened internal margins. Apertural callus narrow, slightly truncate posteriorly in large specimens. Dimensions: long. 18.5, lat. 11.4, alt. 3.2 mm (holotype); long. 14.3, lat. 8.0, alt. 2.8 mm (paratype).

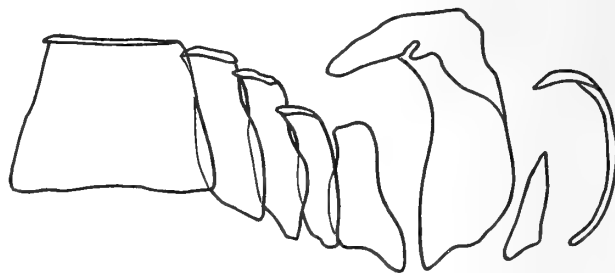


Figure 2

Radula from Holotype of *Lucapinella eleanorae* McLEAN, spec. nov.

**Type Material:** Holotype, Los Angeles County Museum of Natural History, cat. no. 1153; paratype, Stanford University, Paleontological Type Collection, cat. no. 9936. Type Locality: Banderas Bay, Jalisco, Mexico. Dredged, 10 fathoms depth, on bottom of cobbles, off the town of La Cruz, northern shore of Banderas Bay (20° 44' N, 105° 29' W), March 24, 1965. James H. McLean and A. Myra Keen on board the "Sea Quest."



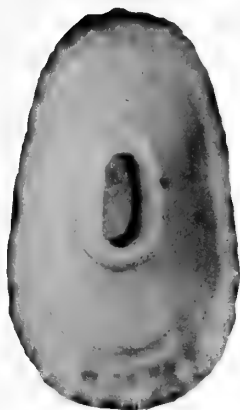


Figure 1

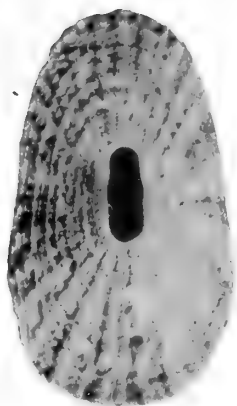


Figure 2



Figure 3



Figure 4

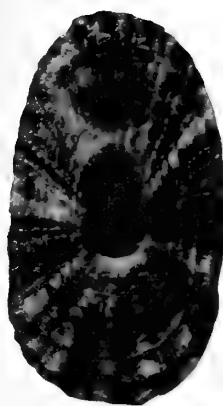


Figure 5

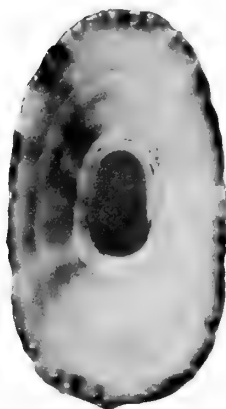


Figure 6



Figure 7

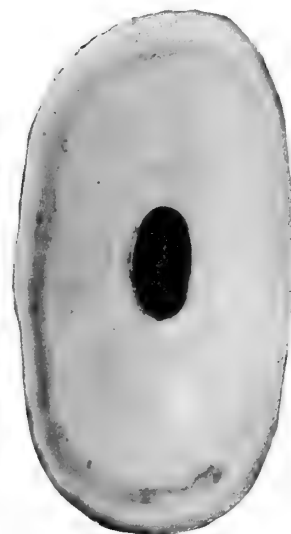


Figure 8

Figures 1 and 2: *Lucapinella callomarginata* (DALL). Holotype USNM 19478, San Pedro, California, x 3.

Figures 3 and 4: *Lucapinella cleanorae* McLEAN, spec. nov. Holotype, LACM 1153, Banderas Bay, Jalisco, Mexico, x 3.

Figures 5 and 6: *Lucapinella milleri* BERRY. Holotype, SUPTC 8588, Puertocitos, Baja California, Mexico, x 6.

Figures 7 and 8: *Lucapinella aequalis* (SOWERBY). SDNHM 30776, Taboga Island, Republic of Panama, x 3.



**Distribution:** Guaymas, Sonora, Mexico, to Santelmo Bay, Panama. Records: Guaymas, Mexico, Roy Poorman (LACM); San Juan del Sur, Nicaragua, H. N. Lowe (SDNHM 30774); Santelmo Bay, Panama (SDNHM 16733). The specimens known from Mexico have been recorded as dredged in 10 to 20 fathoms, but the bathymetric occurrence of the species in Nicaragua and Panama is not known. Dredging along the eastern shore of the Gulf of California has not as yet produced the species.

**Discussion:** Specimens of *Lucapinella eleanorae* have undoubtedly accounted for some reports of *L. callomarginata* in the southern Panamic province. No specimens are represented in the collection of the U. S. National Museum.

*Lucapinella eleanorae* differs from *L. callomarginata* in having a thinner shell, a reddish coloration and an oval rather than elongate aperture. It is larger than *L. milleri*, is more narrow anteriorly, and has a proportionately smaller aperture. It differs from *L. aequalis* in having more pronounced imbricate sculpture, being more narrow anteriorly, and having a proportionately smaller aperture.

I take pleasure in naming the species after Eleanor Dwyer (Mrs. Richard F). Material collected by Mrs. Dwyer has added to our knowledge of Panamic mollusks.

*Lucapinella milleri* BERRY, 1959

(Plate 49, Figures 5 and 6; Text figure 3)

*Lucapinella milleri* BERRY, 1959, p. 109.

**Diagnosis:** Shell small, elongate, sides nearly parallel, ends rounded. Posterior slope of shell slightly concave, posterior margin elevated. Foramen elongate-oval, rela-



Figure 3

Radula of *Lucapinella milleri* BERRY

Rancho El Tule, Baja California, Mexico (LACM). The first two marginal teeth are shown.

tively large, slightly anterior to center, approximately one-fourth the length of the shell. Radial sculpture of closely spaced primary and smaller secondary ribs. Concentric sculpture forming imbrications, pronounced on crossing primary ribs. Color whitish with radiating bands of gray. Apertural callus narrow, internal margin weakly defined. Dimensions: long. 8.6, lat. 4.6, alt. 1.4 mm (holotype).

**Type Material:** Holotype, Stanford University Paleontological Type Collection, cat. no. 8588 (Plate 49, Figures 5 and 6). Type Locality: Puertocitos, Baja California.

**Distribution:** Throughout the Gulf of California and south to Mazatlan. Records: Rancho El Tule, Baja California, C. Willis (LACM); Mulege, Baja California, J. H. McLean (LACM); Puertocitos, Baja California, H. DuShane (LACM); Puerto Peñasco, Sonora, A. Huffman (LACM); Guaymas, Sonora, J. H. McLean (LACM); Mazatlan, Sinaloa, J. H. McLean (LACM).

**Discussion:** *Lucapinella milleri* occurs not uncommonly in the intertidal zone at Puertocitos. It differs from the other species in its smaller size and its relatively large aperture. Shell color varies from grey to reddish.

*Lucapinella aequalis* (SOWERBY, 1835)

(Plate 49, Figures 7 and 8)

*Fissurella aequalis* G. B. SOWERBY, 1835 (1834-1835), p. 127. — G. B. SOWERBY, Jr., 1835 (1832-1841), fig. 56 — REEVE, 1849 (1849-1850), fig. 55.

*Lucapinella aequalis* (SBY.) — PILSBRY, 1891 (1888-1898), vol. 12, p. 197, pl. 31, fig. 24. — KEEN, 1958, p. 251, fig. 28.

**Diagnosis:** Shell elongate, sides nearly parallel, anterior end slightly narrowed, ends rounded. Foramen large slightly anterior to center, one-fourth to one-fifth of the shell length. Base of shell nearly flat. Radial sculpture of low primary, secondary and tertiary ribbing, becoming nearly obsolete in some specimens. Major ribs showing some evidence of imbricate sculpture on crossing concentric growth lines, imbricate sculpture often obsolete. Color whitish with dark radial banding, dark banding frequently covering major portion of shell. Internal margin thickened on mature specimens. Apertural callus narrow, no evidence of posterior truncation. Dimensions: long. 23.3, lat. 12.8, alt. 4.0 mm (SDNHM 30776).

**Type Material:** Probably in the British Museum (Natural History). Type Locality: "St. Elena, West Colombia (on dead shells at a depth of from six to ten fathoms), Cuming."

**Distribution:** Port Guatulco, Mexico, to Ecuador (KEEN, 1958). Records: Puntarenas, Costa Rica, H. N. Lowe

(SDNHM 30757); Montijo Bay, Panama, H. N. Lowe (SDNHM 30775); Taboga Island, Panama, H. N. Lowe (SDNHM 30776).

**Discussion:** The specimen cited above from Montijo Bay, Panama, is the only shell examined that shows evidence of the imbricate sculpture characterizing the genus. In the absence of this specimen, the inclusion of *Lucapinella aequalis* in the genus could be seriously challenged. The more frequently occurring forms of *L. aequalis* have obsolete imbricate sculpture.

*Lucapinella aequalis* is easily distinguished by its obsolete imbricate sculpture. In addition, it has more nearly parallel sides than either *L. callomarginata* or *L. ele-anorae*. It reaches a larger size and has a relatively smaller aperture than *L. milleri*.

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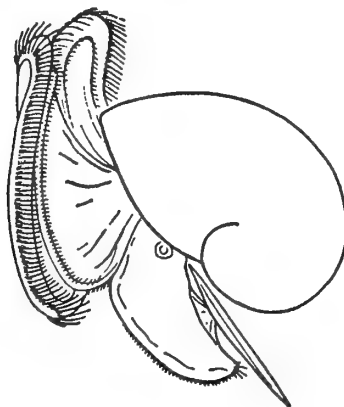
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## First Canadian Report of the Sacoglossan *Elysia chlorotica* GOULD

BY

KANIAULONO H. BAILEY

AND

J. S. BLEAKNEY

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UNTIL VERY RECENTLY the range of *Elysia chlorotica* GOULD, 1870, a large emerald green sacoglossan of brackish water, was reported as Massachusetts to New Jersey (JOHNSON, 1934; MINER, 1950). Even in the "Key to the Invertebrates of the Woods Hole Region" (R. I. SMITH, 1964) the reader is referred to MINER for distributional data. The genus is not listed in ABBOTT's "American Sea Shells" (1954 edition) although 34 genera of the closely related order of the nudibranchs are treated and figured. In 1960, PFITZENMEYER extended the range southward through the accidental discovery of several specimens in Chesapeake Bay, Maryland. A major northward range extension is reported here with the discovery of *Elysia chlorotica* in the salt marshes of the Minas Basin, Nova Scotia. A preliminary annotated list of the fauna of the Minas Basin (BOUSFIELD & LEIM, 1959) treated the mollusks in some detail but did not include any sacoglossans or nudibranchs.

For animals that prefer the pools and shallows of an intertidal habitat, the Minas Basin is an extremely demanding habitat. The mean tidal range is in the order of 38 feet which exposes some 153 square miles of the bottom of this 435 square mile basin twice daily. (The reader is referred to BOUSFIELD & LEIM for further hydrographic details.) Consequently, shallow water and tide pools are a fleeting thing on these well drained mud flats. The *Elysia* from Chesapeake Bay (PFITZENMEYER, op. cit.) were found associated with *Zostera*, *Potamogeton* and oyster shells, none of which occurs in the Minas Basin. The only standing water at low tide is firstly, minor pools around the bases of individual rocks scattered over the flats; secondly, even rarer pools in sandstone outcroppings; and thirdly, the permanent pools, ponds

and ditches in the extensive *Spartina* marshes that border much of the Minas Basin. Some 44054 acres of these Minas Basin salt marshes have been reclaimed by dykes for crop and pasture land thus destroying much of the original marsh land habitat.

The *Elysia* were first discovered in ponds and trenches six inches to three feet in depth and dominated by algae of the Cladophorales and the halophyte *Ruppia*. Since October 1965, many ponds have been examined at the west end of the Minas Basin but only two limited areas have thus far yielded specimens of *Elysia*. However, at these sites *Elysia* is common and occasionally abundant. Nevertheless, even within one pond this large slug has often been found more easily in a restricted area of the pond and often not at all a few feet away. This may account for the inability to find specimens in January, 1966, when an ice cover of 9 $\frac{3}{4}$  inches was over one particular pond. Two holes were cut through the ice, but no *Elysia* could be fished out with random scoops of algal masses. Yet on March 15 the ice was gone and adult *Elysia* were again evident. On May 31 strings of eggs were noted for the first time and were found attached to algal filaments and to the *Ruppia*.

Most surprising was the discovery on several occasions in July and August 1966 of many small *Elysia* on mats of *Vaucheria*, which has not previously been reported for this species. They were usually found in damp depressions around the bases of the *Spartina*, but were nevertheless exposed to the air and the euryhaline extremes of rain and high tides. In both Europe and North America *Vaucheria* alga is considered the natural microhabitat of another slug, *Alderia modesta* LOVÉN, 1844. We did find

this latter species at the same time and often in company with *Elysia*.

From the limited literature on the species it is apparent that it can exist over an amazing gamut of habitats; it can tolerate wide fluctuations in salinity, temperature, oxygen; it can be dredged from ten feet of water or taken in brackish ponds or on exposed cushions of *Vau-cheria*; it is active throughout the year, and both during

the day and at night; and it frequents a variety of substrates and a variety of plants. In spite of such wide ranges of environmental tolerance, it is, nevertheless, particularly sensitive to some factor or factors, and in the Minas Basin at least it has a more limited and discontinuous distribution at the local level than other species of mollusks that one usually considers as good examples of stenoeccious organisms.

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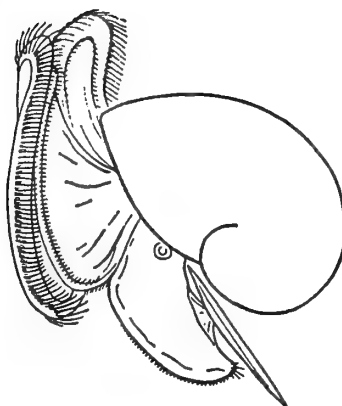
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## NOTES &amp; NEWS

# Additional Remarks on the Range of *Trivia myrae* CAMPBELL

BY

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RECENT CORRESPONDENCE received following the publication of my paper on the range of *Trivia myrae* CAMPBELL (DONOHUE, 1966) suggests that some clarification may be in order. The legend to the figure reads "Map of the Gulf of California, showing the localities from which *Trivia myrae* has been reported." As it stands, this legend is correct and logically consistent, but a too casual reading of it without careful reading of the text, might lead some to infer that all of the localities shown on the map represented localities from which this taxon had been reported (up to the time of the writing of the paper). In the text one finds that *T. myrae* had been reported from the following localities: the channel between Loreto and Carmen Island, off Monserrate Island, off Coronados Island, off Puerto Escondido, off Punta Final, and Puerto Peñasco; these are, of course, designated on the map. Three additional localities, viz. Puertecitos, Guymas, and Mazatlán, are also shown on the map, but it is explicitly stated in the text that *T. myrae* had not (as yet) been reported from them.

Meanwhile, I have been informed of the following additional collecting information for *Trivia myrae*:

- 1) from Mrs. Helen DuShane: outside San Carlos Bay near Guymas in 17 fathoms; outside Puertecitos in 6 fathoms; one mile off Rancho Buena Vista (Baja California del Sur) in 10 fathoms.
- 2) from Mrs. Elsie Marshall: San Carlos Bay, Guymas, in 17 fathoms (probably from the same catch referred to above).
- 3) from Dr. William Emerson: Bochichibampo Bay. Guymas, dredged.

<sup>1</sup> Present address: Laboratorium für Organische Chemie, E. T. H., Zürich, Switzerland.

<sup>2</sup> Contribution No. 295

It thus appears that my suggestion that *Trivia myrae* should be sought at other mainland localities on the Gulf of California was unnecessary, because it had already been found there.

Finally, Dr. Emerson (private communication) has expressed the opinion "I see no reason why this species should not occur in suitable habitats throughout the Gulf of California, and possibly as far south as Panama Bay." Time will tell.

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9 (1): 35-36; 1 map (1 July 1966)

## Gut Content and Radula Illustration of *Bathybembix bairdi* (DALL, 1889)

BY

JEAN A. MERRIMAN

(1 Text figure)

DALL, 1889, PUBLISHED A BRIEF ACCOUNT OF *Bathybembix* (= *Turricula*) *bairdi* in which he described in a general the features of the radula. He considered other morphological features and stated that "the gut was crammed with a greenish mud consisting of disintegrated Foraminifera."

The radulae of four specimens were removed, stained with fast green, and prepared in slides according to the method used by FRITCHMAN (1960). The intact radulae were photomicrographed and then teased apart for microscopic examination. Utilizing photomicrographs and the teased radulae a composite illustration was made of the radular teeth (see Figure 1).

The guts of these four specimens, all collected in Bodega Bay, California, were examined. The greenish mud was found to be glauconite, an amorphous iron potassium silicate. In addition to the glauconite, the following taxa of Foraminifera were found: Rotaliidae, *Uvigerina*, *Virgulina*, *Bolivina*, *Cibicides*, *Globigerina*, *Buliminella*, and

*Bullimina*. Three genera of Diatoms and three genera of Radiolarians were observed as well as one small gastropod.

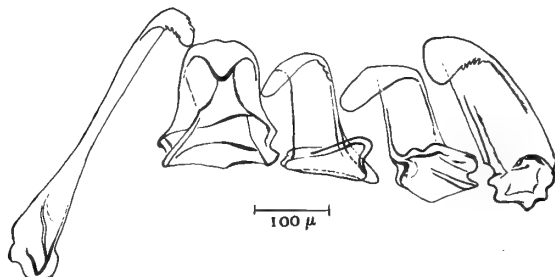


Figure 1

*Bathybembix bairdi* (DALL, 1889)

Uncinus; Central Tooth; First, Second, and Third Laterals. Note: The third lateral has been rotated 50° to show the bar on the stem which in the intact radula fits into the slot on the base of the second lateral. The blades are very flexible and may assume various positions.

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1960. Preparation of radulae. The Veliger 3 (2): 52-53 (1 October 1960)

## Type Locality Designation for *Dirona aurantia* HURST, 1966

ANNE HURST

Zoology Department, University of Reading  
Reading, Berkshire, U. K.

THE ORIGINAL DESCRIPTION of *Dirona aurantia* HURST, 1966 was made from a collection of specimens pooled from three localities. The type specimen was chosen from these not knowing from which of the areas of collection

it had come. For this reason a type locality could not be given more closely, but on consideration of the area and the distribution of this new species, it has been decided that West Blakeley should be designated as the type locality. — Geographical position: West Blakeley, 30-23 fathoms; 48° 34' 30" N; 122° 50' 36" W.

## A. M. U.

The Meeting of the A. M. U. this year will be held in Ottawa, Ontario, Canada, from July 31 to August 4. Arrangements for the conference are in the hands of Dr. A. C. Clarke, Jr., First Vice President. For the various sessions rooms will be available at the National Museum of Canada and at Carleton University.

Principal officers for 1967 are: Dr. Leo G. Hertlein, President; Dr. Clarke, First Vice President; Mr. Gale G. Sphon, Second Vice President; Mrs. Margaret Teskey, Secretary and Mrs. H. B. Baker, Treasurer.

Members of the American Malacological Union, Inc. will receive details regarding the meeting directly from the central office. Non-members are invited to attend the meetings and may obtain details by writing to Mrs. Teskey in Marinette, Wisconsin.

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\$12.90 all other foreign countries.

## BOOKS, PERIODICALS, PAMPHLETS

### Shell Collecting

An Illustrated History by S. PETER DANCE

University of California Press: Berkeley and Los Angeles, California. Pp. 1 - 344, 35 plates (3 in color) ; text figures. \$10.00.

The book jacket states, "Here, for the first time in book form, is a wealth of detailed information, much of it previously unpublished, on shell collecting, shell collections, shell auctions, and shell books, and on the men and women whose lives have been affected to a greater or lesser degree by the shell-collecting habit." A book constructed of such materials could have been dull indeed, but this one is not. The story is skillfully told, and the masses of documentation are made to fit in so naturally that the reader is unaware of how much solid content is packed into it. The little human touches that make for easy reading are never overlooked.

The historical approach is used, tracing the development of shell collecting through its various eras - pre-Linnean, Linnean, Lamarckian, Cumingian, and so on, up to the time of World War I. The emphasis, of course, is on the great collections of Europe, for here is where the major activity centered, but other areas are not neglected. In the second part of the book, chapters are devoted to the stories of some of the most sought-after shells, such as *Conus gloriamaris*; and appendixes bring together information not readily available elsewhere - conchological cabinets of the early 18th century; deep-sea expeditions that collected shells; and finally a guide to collections, in the form of a list of some 500 authors' names, arranged alphabetically, with notes on the present location of their material. A bibliography of 337 titles concludes the work - in itself a valuable contribution.

From time to time there have come from the British Museum short papers, such as those of the late Guy Wilkins, that have provided tantalizing glimpses into the possibilities of historical research there. Peter Dance has now given us a full-scaled review of the field, bringing

into focus the background of that odd and delightful mixture of natural history, esthetics, and science that is conchology. As Dr. C. M. Yonge in the last paragraph of his "Foreword" to the book remarked: "Just such a book needed to have been written, and I do not think it could have been done better." With this the present reviewer is in agreement. The work is remarkably free of typographical errors and slips of the pen (the only one noticed is "*Phyllonotus pinnatus*" on page 140 where *Pterynotus* probably is intended). There is too much interesting information here for it all to be absorbed during a single reading, and one will want to browse again and again. The book should find an honored place on the shelves of any shell enthusiast, whether beginner or professional.

MK

### The Neotropical Land Snail Genera

*Labyrinthus* and *Isomeria*  
(Pulmonata, Camaenidae)

by ALAN SOLEM. Fieldiana: Zoology, Vol. 50, 226 pp., 61 figures. Field Mus. Nat. Hist., Chicago, 31 May, 1966.

This is a thorough revision of the two genera named in the title. Close to 2000 specimens of approximately 70 species were examined. Excellent line drawings of anatomical details of a number of critical species as well as fine photographs of the shells and apertures of shells accompany the lucidly written text. Synonymies are also included.

RS

### Mollusca from the Upper Cretaceous Jalama Formation, Santa Barbara County, California

by DONALD H. DAILEY & W. P. POPEÑO. Univ. Calif. Geol. Sci., Vol. 65: pp. 1 - 29; 6 pls.; 3 text figs. 21 October 1966. Univ. Calif. Press Berkeley and Los Angeles. \$1.50.

In this survey of an interesting stratum the authors include the description of ten pelecypods and five gastropods as new to science. The descriptions are lucid, well illustrated and all desirable information about the type specimens is provided. There are also equally thorough accounts of three species previously known.

RS

### Type Specimens in the California Academy of Sciences, Department of Invertebrate Zoology

by CHARLES R. STASEK. Occ. Papers Calif. Acad. Sci. no. 51. 38 pp. 15 April 1966.

This is a list of all principal type specimens in the collection of the Academy, excepting the types of species

based on shells, that are preserved in the type collection of the Department of Paleontology. The collection does include mollusks; also of importance is the fact that for many taxa microscope slides have been used in the original descriptions and these slides are also preserved. The paper will be of great value to taxonomists in many fields.

RS

#### The Eye of the Giant Clam (*Tridacna maxima*)

by CHARLES R. STASEK. Occ. Papers Calif. Acad. Sci. no. 58. 9 pp.; 5 figs. 19 August 1966.

A brief but thorough paper dealing with the hyaline organ of the giant clam.

RS

#### Harold Heath's Type Solenogasters (Mollusca, Amphineura, Aplacophora) in the California Academy of Sciences, Department of Invertebrate Zoology

by CHARLES R. STASEK. Occ. Papers Calif. Acad. Sci. no. 52. 7 pp. 15 April 1966.

The types listed in this publication were transferred to the California Academy of Sciences from Stanford University, where Harold Heath had done his classical work on this extraordinary group of mollusks. Since the material forms such a special block of type specimens, this list was not included with another report on types in the same collection.

RS

#### Lista Preliminar de los Mytilidae Brasileños con claves para su determinación y notas sobre su distribución.

by MIGUEL A. KLAPPENBACH. Academia Brasileira de Ciências, Sep. Vol. 37, Suppl. "An. Acad. Bras. Ciên.", pp. 327 - 352; plates 1 and 2; September, 1965.

This paper deals with the Mytilidae of Brazil. The members of this family are arranged in 12 genera, 21 species and subspecies and one species cited only as to genus. These are discussed, keys are included, and 13 are illustrated on two plates. Eleven species and subspecies are believed to be typical of the Antillean and Caribbean provinces, 8 are probably typical inhabitants of Brazilian waters (some of these range to the north and to the south of that country), and 3 which live in Southern Brazil are members of the Argentinian molluscan province.

For additional information concerning the species cited in the present paper (p. 340) as "*Mytella falcata* (D'ORBIGNY, 1846)", the reader should refer to a later paper by

the same author ("Sobre las fechas de las especies de Mytilidae que describiera A. D'Orbigny", Neotropica, Vol. 11, No. 36, pp. 118 - 120, December 1, 1965) in which he discusses the nomenclature of this species. There is a prior *Mytilus falcatus* MÜNSTER in GOLDFUSS, 1837; therefore the author believes that the Brazilian species should take the specific name *Mytilus charruanus*, a name proposed for this species by D'ORBIGNY in 1842.

LGH

#### Introduced Mollusks of Western North America

by G DALLAS HANNA. Occ. Papers Calif. Acad. Sci. no. 48. 108 pp.; 85 figs.; 4 pls. in color. 16 February 1966

A thorough historical review of the pertinent literature, amplified with numerous records from various sources, covering accidental as well as intentional (commercial) introductions of mollusks to the western United States, including Hawaii.

RS

#### Some Marine Molluscs from the Southwest Coast

by WILLIAM H. COLE & BEATRICE HARRIS. publ. by the authors. Address: 288 Second Street South, Naples, Florida 33940. 21 pp.; colored illustrations planned for later addition.

This publication is an unusual one in that it approaches a fairly common subject in a novel fashion: a checklist of frequently encountered mollusks. The novel aspects include the following features: Species are listed alphabetically, without regard to classification, by the scientific names. Below each scientific name is given a brief explanation with the derivation of the name; the class to which the species belongs is given by a bold face capital letter (P for pelecypods and G for gastropods) and finally there is given a "recommended" common name. This list is designed to accompany display cases containing all the listed species, that have been distributed to the schools in Naples. However, the value of the booklet is augmented by a chapter on the classification of plants and animals, another chapter giving hints on the proper pronunciation of the scientific names; still another chapter gives thumb-nail sketches of the lives of some of the better known conchological authors and the booklet closes with two indexes.

Further information about the booklet - which, incidentally is 8½ x 11 inches - and presumably the project of the Naples Shell Club, Inc. may be obtained from the Secretary of the Club.

RS

**THE VELIGER** is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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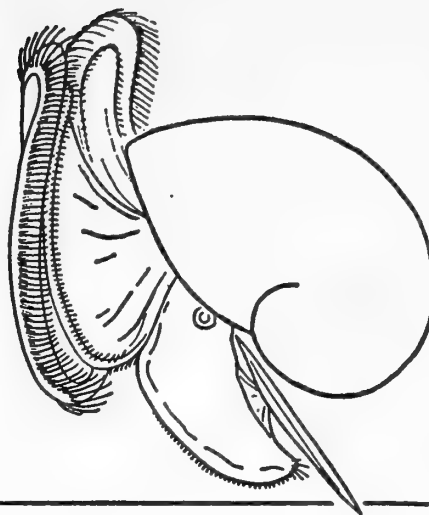
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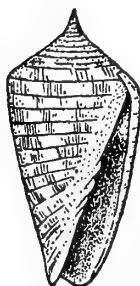
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, Subdivision, SECTION,  
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).  
**New Taxa**

Responses of Two Haliotid Gastropods (Mollusca),  
*Haliotis assimilis* and *Haliotis rufescens*,  
to the Forcipulate Asteroids (Echinodermata),  
*Pycnopodia helianthoides* and *Pisaster ochraceus*

BY

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(Plates 50, 51; 2 Text figures)

## INTRODUCTION

SINCE 1949 THE STUDY OF RESPONSES of gastropods stimulated by asteroids has received much attention. The stimulating substance is liberated from the tube foot epidermis (BULLOCK, 1953; FANGE, 1963; FEDER, 1963, FEDER & LASKER, 1964; KOHN, 1961; MARGOLIN, 1964 a, b; YARNALL, 1964). Some evidence (FEDER, 1959, 1963; MARGOLIN, 1964 a, b) indicates that the response is part of a predator-prey escape pattern. Other animals tested exhibit similar responses but information is lacking as to their exact relationships with the asteroids. Responses to asteroids are not limited to gastropods. Experiments with pelecypods (RAY, 1959), actinozoans (ROBSON, 1961, 1963; YENTSCH & PIERCE, 1955) and other echinoderms (MACGINITIE & MACGINITIE, 1949) also showed responses.

Cox (1962) lists a zone from the intertidal to 540 feet as the depth range for *Haliotis rufescens*, with the majority of animals found at 20 to 50 feet. The range of *Haliotis assimilis* is given as 10 to 120 feet with major concentrations between 70 and 100 feet. These abalones overlap in their habitats, but *H. assimilis* is found in much smaller numbers. LIGHT (1954) lists *Pisaster ochraceus* and *Pycnopodia helianthoides* as intertidal animals but *Pisaster ochraceus* usually does not extend much beyond the intertidal, while *Pycnopodia helianthoides* is a permanent resident of subtidal waters. Dredging in Puget Sound, Washington, rarely produced a specimen of *Pisaster ochraceus* from the deeper waters, yet large numbers of *Pycnopodia helianthoides* were easily obtained from like

depths. The earlier work of BENNETT (1927) and later experiments by BULLOCK (1953) and FEDER (1963) indicate that haliotid gastropods respond to stimulation by asteroids.

For this study only the common forcipulate sea stars in the intertidal (*Pisaster ochraceus*) and the subtidal (*Pycnopodia helianthoides*) were used to initiate responses in the intertidal abalone (*Haliotis rufescens*) and a subtidal abalone (*H. assimilis*).

## METHODS AND MATERIALS

Laboratory experiments were carried out at the Brebes Marine Laboratory, Morro Bay, California. Since 1964 this private facility has been concerned with the feasibility of commercially raising *Haliotis rufescens* and related species of abalone. Several hundred abalones of several sizes and species are available. Specimens of *H. rufescens*, for instance, range from 0.5 mm to 28 cm in shell length.

Holding tanks (24" x 48" x 18"), water tables (96" x 24" x 4"), and supplementary trays (36" x 24" x 3") are resined plywood. The supplementary trays nest into the holding tanks and water from the trays cascades into the tanks. Several of the supplementary trays were placed on supports and supplied with running sea water from the system. By changing the position of the inlet hose a stream of water could be directed anywhere across the tray, then drained into the main drain channel. To minimize current interactions the hose could be removed. This permitted star-liberated substances to diffuse normally throughout

the water or to be directed at the experimental abalone. Trays were scrubbed and filled with clean sea water after each experiment. Animals were rotated so that several days elapsed between successive stimulations for a particular animal. After testing, very sensitive animals like *Haliotis assimilis* were kept in separate tanks away from untested animals.

An abalone was placed on the tray in the water stream and allowed to become quiet. To test for diffusible substances, the asteroid was then placed in the water stream near the hose end. In a subsequent test the abalone was checked for its ability to react to diffused substances in quiet water. Each test was repeated. Experiments were also performed, in duplicate, in which the tube feet, ambulacral grooves and aboral epidermis of the stars were touched to the tentacles, epipodium and foot of the abalones. Other tests are described in the text.

#### Species of animals used:

##### Gastropoda (Prosobranchia)

*Haliotis assimilis* DALL, 1878

*Haliotis rufescens* SWAINSON, 1822

##### Asteroidea (Forcipulata)

*Pisaster ochraceus* (BRANDT, 1835)

*Pycnopodia helianthoides* (BRANDT, 1835)

*Haliotis* is a prosobranch gastropod, its limpet-like shell bearing a row of small holes to allow a more direct exit of the exhalant current from the mantle cavity. The animal is benthic in nature, moving slowly over rocks on the bottom on a broad, muscular foot as it feeds on algae.

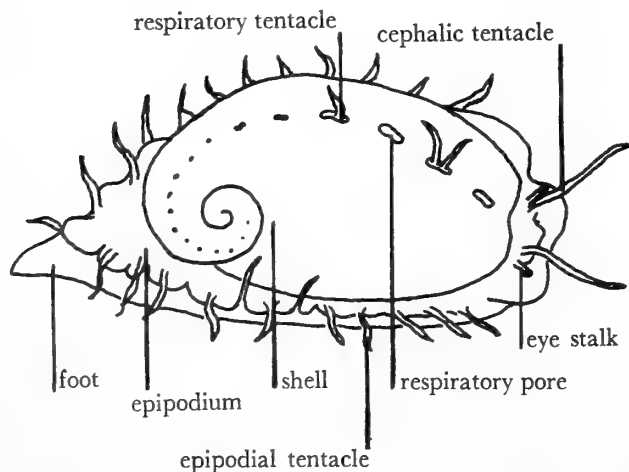


Figure 1

*Haliotis* spec.

A raised collar, the epipodium, encircles the foot dorsally and bears numerous tactile epipodial tentacles. The head has three pairs of tentacles: a short and a long pair of tactile cephalic tentacles and a more anterior pair with eyes at the tips. Several mantle tentacles project through the respiratory pores in the shell (see Text figure 1).

Forty-one individuals of *Haliotis assimilis* and 105 of *H. rufescens* were tested; 9 *Pisaster ochraceus* and 4 *Pycnopodia helianthoides* were used. Abalones tested consisted of mixed populations: freshly-caught animals, specimens collected and then raised in the laboratory, and animals raised from zygotes obtained from laboratory stock. No attempts were made in these experiments to determine differences between freshly-caught and laboratory-raised animals. All stars and abalones were obtained from the intertidal and subtidal waters off Morro Bay and Cayucos, California.

#### RESPONSES OF *Haliotis assimilis* to *Pycnopodia helianthoides*

##### Stream Responses

Specimens of *Haliotis assimilis* were placed on the tray in the stream of water, approximately 30 cm from the inlet hose. *Pycnopodia helianthoides* was held against the hose end and allowed to attach. The water stream passed over the oral surface of the star, down the table and over the abalone. Within 25 seconds (average time 15 seconds) the abalone extended the cephalic tentacles to maximum length (Plate 51, Figure 9), vibrating the tips rapidly and sweeping the tentacles back and forth through the water. The epipodium was protruded from beneath the shell within 36 seconds (average 25 seconds), its tentacles waving about in the water, the lobes swelling and extending stiffly from the body. Movement in an anterior direction began within 70 seconds (average 35 seconds), the animal moving randomly to the left, right, or straight ahead. Speed of locomotion increased with time, until the abalone was moving at several times normal speed. As the animal moved away from the stimulation on a left or right pathway the shell usually would be lifted away from the foot and be twisted rapidly back and forth through an arc from 30° to almost 180° (Plate 50, Figure 1). Depending on the sensitivity of the particular animal this twisting would start and stop several times as the animal moved away. The abalone moved rapidly to the edge of the tray, then along the side of the tray to a corner, or perhaps half-way or completely around the tray. Contact with the edge or corner of the tray usually produced a climbing reaction, with the animal moving up the side of the tray out of the water, and over the edge to fall on



the floor. Plate 50 shows a series illustrating these reactions. A majority of the animals tested also liberated quantities of a viscid mucus from the respiratory pores during flight (Plate 50, Figure 2). Animals re-encountering the star during flight recoiled sharply upon minimal contact, turned quickly away, and began a new flight response. In no case did an abalone crawl over the star to escape; it always recoiled and then moved away to left or right. The rapid locomotion noted barely resembled normal gliding movement. The anterior portion of the foot was raised from the substrate and extended far ahead, giving a leaping effect. The foot and body rocked from side to side as the animal moved. The margin of the foot undulated rapidly and the shell was usually held above the body in a mushrooming effect.

The above set of responses occurred with every specimen of *Haliotis assimilis* tested with *Pycnopodia helianthoides*; variations in speed of response occurred, but the pattern remained fairly constant. Experiments using the stream of water without a sea star elicited no response.

#### Responses to Contact

Contact was either effected manually by the observer, or randomly, the abalone being allowed to encounter the asteroid as it moved about. No significant difference was observed in comparing these contact responses. Contact with either tube feet or aboral epidermis of the asteroid always elicited positive responses. Contact was as minimal as possible, usually a slight touch.

Responses to contact followed the same pattern as with stream reactions, with all abalones tested. Plate 50, Figure 3 shows both twisting and climbing induced by contact with tube feet. Flight initiated by contact with tube feet was always away from the point of stimulation; anterior if the posterior epipodial tentacles were touched, left when touched on the right side, right when stimulated on the left, and posteriorly when cephalic tentacles were contacted. The abalone did not creep over the star in avoiding it, and in moving along the side of the tray above the star the shell was held away from the surface of the star.

A summation of contact responses is presented in Figure 2, Diagram a. The abscissa indicates the shell length in centimeters, the ordinate the strength of flight response. The strength of the response is indicated by an arbitrary scale ranging from 0 (no response) to 10 (full flight response: extremely rapid locomotion; shell twisting; emission of mucus; and climbing reaction). Regardless of size, specimens of *Haliotis assimilis* reacted with strong flight responses. All responses were 8 or above in strength, indicating that contact with a star was a major irritation effecting the responses.

Larger animals responded more slowly (50-70 seconds) to initial stimulation, but full flight responses (8-10) resulted. The upper size limit for *Haliotis assimilis* is 15 to 16 cm. Smaller animals (3-8 cm) continued to react for longer periods of time than larger ones, sometimes for as long as 30-40 minutes after being tested. Animals returned to holding tanks after testing stimulated flight responses in other abalones present. *Haliotis assimilis* touched briefly on the posterior tentacles by the tube feet of a small *Pycnopodia helianthoides* crawled rapidly along an eight-foot water table, against the water flow, climbing the far edge of the table and falling to the floor. During this travel it crawled over and touched two other abalones: one *H. rufescens* and one *H. assimilis*. Within 6-10 seconds the second *H. assimilis* also crawled to the near edge of the table, and over, and fell to the floor; *H. rufescens* displayed no response. A third *H. assimilis*, six feet away from the stimulation point and one foot to one side of the crawling abalone responded without contact within 15 seconds after the passage of the stimulated abalone. Several repetitions yielded like results.

The most rapid and also strongest flight responses resulted from stimulations of the posterior epipodial tentacles; lesser responses occurred on stimulation of the lateral or anterior epipodial tentacles. Stimulation of the posterior tentacles during flight usually caused the specimen to "surge" ahead, sometimes almost in a leaping manner. The cephalic tentacles showed sensitivity upon initial contact, but secondary stimulation during flight did not give as strong a response as secondary stimulation of epipodial tentacles. Flight was also accelerated by secondary stimulation of the posterior respiratory tentacles (extending through the posterior pore); stimulation of the anterior respiratory tentacle(s) gave a somewhat weaker response. Touching either the epipodial surface or the foot with the tube feet of the star resulted in a positive response.

Flight response continued up to 35-40 minutes from stimulation; flight length in centimeters exceeded 250 to 260 cm.

Repeated stimulation at five-minute intervals showed that *Haliotis assimilis* was still responding positively with little drop in strength of response after 195-230 minutes. FEDER (1963) and BULLOCK (1953) mention that after several stimulations the gastropod becomes desensitized and fails to respond. Mucus emitted by *H. assimilis* fouled the aboral surface of the asteroid to the point where it was felt that continuation of the experiment was useless. MARGOLIN (1964a), using *Diodora aspera* and *Pisaster ochraceus*, noted complete cessation of response after 320 to 390 minutes.

*Pycnopodia helianthoides* was allowed to remain in a dish of sea water for 30 + minutes. This "sea-star water" was then pipetted over *Haliotis assimilis*. Within 15-25 seconds a typical flight pattern was exhibited. Response strength in these experiments was 8 to 10 for all abalones tested.

Isolated tube feet induced the same response as contact with tube feet on the sea star. When pipetted into the water the detached tube feet produced a flight response immediately upon contact with an abalone. When none of the tube feet touched an abalone a response was observed after 60-70 seconds.

When glass, metal or wood probes were used to stimulate the specimens no flight response was noted; clamping down of the animal and tentacle retraction resulted. When, however, the probes were first rubbed over the oral surface of the sea star, subsequent contact produced a weak (6-7) response. Touching the foot, tentacles and epipodium with empty shells of *Tegula funebris*, *Acmaea* spp., *Haliotis* spp., and *Mytilus californianus* gave negative results.

#### RESPONSES OF *Haliotis assimilis* TO *Pisaster ochraceus*

##### Stream Responses

Time of responses to a stream of water crossing the oral surface of a star was much slower with *Pisaster ochraceus* than with *Pycnopodia helianthoides*. Of 41 abalones tested, 29 showed no significant tentacle activity for periods ranging from 1 to 6 minutes. When tentacle activity occurred, it was followed by minimal epipodial activity, extension from under the shell, and slow back-and-forth movement. After 1 to 6 minutes the abalone sometimes moved away from the star in a 90° to 180° turn, then became quiet. Of 41 animals tested, 16 displayed tentacle activity alone, 22 exhibited tentacle and turning reactions, and 13 gave typical flight responses of 3-5 strength, consisting of flight only; none of the other responses noted for *Haliotis assimilis* occurred. Flight responses were displayed only by animals smaller than 9 cm.

#### Responses to Contact

Figure 2, Diagram b shows contact responses of subject animals. Over 50% of the animals showed a response below 8 in strength. Specimens above 10 cm in length also showed a 50% response; 8 gave responses above 6, while 8 indicated a response below 6 in strength. This is in contrast to the reaction with *Pycnopodia helianthoides* where all animals exhibited strong flight responses. Only 1 of the smaller abalones (below 10 cm) gave a negative response; the rest were 5 or above in strength of responses. Flight responses when elicited showed the same pattern as with *Pycnopodia helianthoides*; the responses, however, took longer to initiate. Several stimulations were often required to give a flight response, and often the responses of shell twisting, mucus emission, and climbing occurred only after stimulation during flight. Differences in the sensitivity of the cephalic, epipodial and respiratory tentacles resulted as they did with *Pycnopodia helianthoides*; positive responses were also observed when the epipodium or foot of the abalone was touched by tube feet.

Specimens of *Haliotis assimilis* more than 10 cm in shell length exhibited an almost negative reaction to initial contact with tube feet or aboral epidermis; when the tube feet touched the foot or epipodium the abalone usually clamped down firmly (Plate 50, Figure 6). Continued stimulation sometimes produced a strong pushing reaction of the abalone shell against the arm of the star. In some instances this was repeated several times, after which the star moved away. Larger animals utilized this pushing action and the violent twisting of the shell already described instead of flight. Specimens below 10 cm in length usually fled with shell twisting accompanying the flight response. Usually only the tube feet of *Pisaster ochraceus* evoked a positive response. Stimulations with the aboral epidermis seldom produced flight responses, sometimes a shell twisting response, but usually only minimal tentacle activity. In several cases the abalone crawled over the aboral surface of the sea star; it did not crawl over the up-turned oral surface. When forced to crawl over the aboral surface of asteroid arms the abalone did so very rapidly, with the shell held high above the foot. "Sea-star

#### Explanation of Plate 50

##### RESPONSES TO *Pycnopodia helianthoides*

Figure 1: *Haliotis assimilis* twisting shell.

Figure 2: *Haliotis assimilis* liberating mucus.

Figure 3: *Haliotis assimilis* twisting and climbing.

Figure 4: *Haliotis rufescens* showing posterior epipodium covering response.

Figure 5: *Haliotis rufescens* showing posterior respiratory tentacle epipodial covering response.

Figure 6: *Haliotis rufescens* (10.3 cm) clamping down.

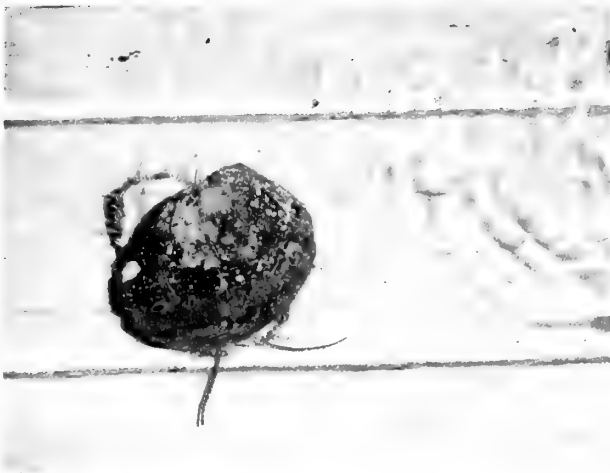


Figure 1

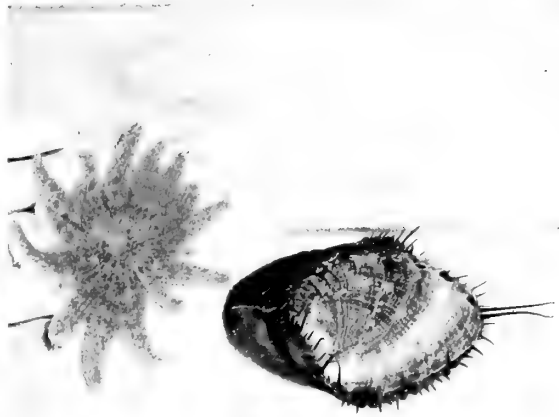


Figure 4

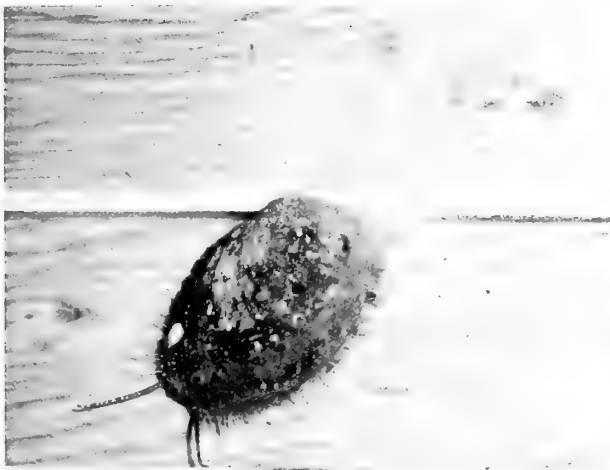


Figure 2



Figure 5

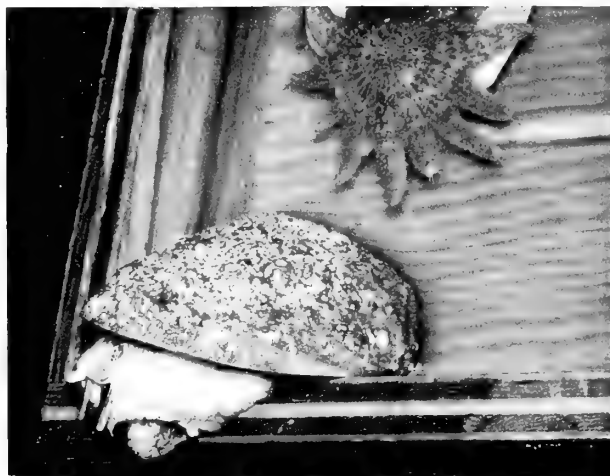


Figure 3



Figure 6



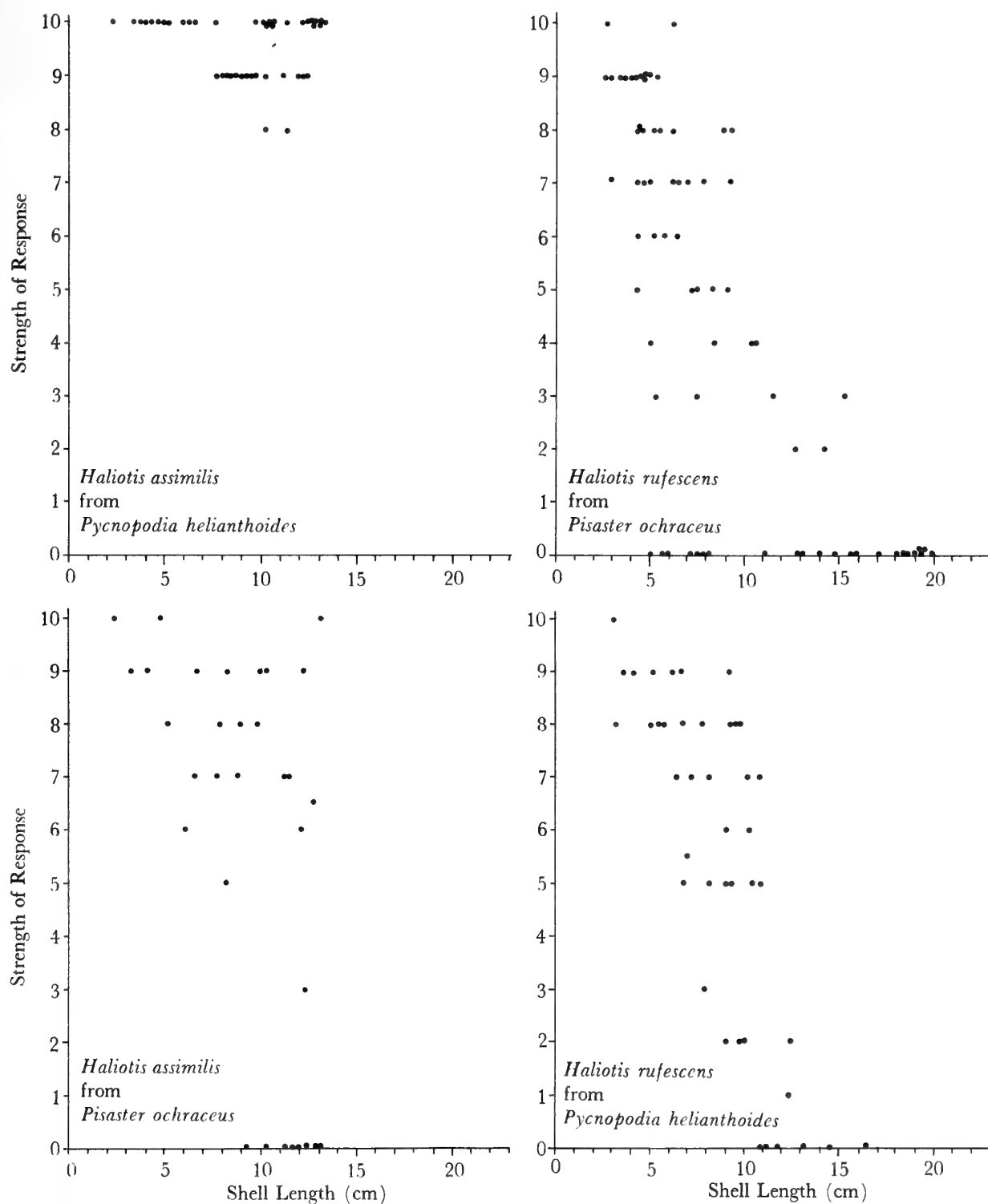


Figure 2

Flight Responses to Tube Feet Contact.

Diagram a: *Haliotis assimilis* from *Pycnopodia helianthoides*.Diagram b: *Haliotis assimilis* from *Pisaster ochraceus*.Diagram c: *Haliotis rufescens* from *Pisaster ochraceus*Diagram d: *Haliotis rufescens* from *Pycnopodia helianthoides*

Strength of response is based on an arbitrary scale measured in terms of: speed of flight responses, shell twisting, mucus emission, climbing out of experimental tray.

water" pipetted over 34 animals gave flight responses in 6 abalones; others showed only tentacle and epipodial activity, with some side-to-side turning. Stimulation with glass, metal and wood probes and with empty shells induced no significant responses. Stimulation with these objects, after they were rubbed over the oral surface of the sea star gave weak responses in a few instances.

#### RESPONSES OF *Haliotis rufescens* to *Pisaster ochraceus*

##### Stream Responses

Time lags before responses ranged from 48 seconds (in the smaller animals) to 5 minutes (in the larger [10 to 15 cm]) ones. Animals larger than 15 cm were not tested in the experimental tray as the water was not deep enough to cover their shells. Of 21 larger animals tested, 8 showed some tentacle activity, 7 turned away 90° to 180°, and 6 showed a minimal flight response, without shell twisting, mucus emission, or climbing reactions. The smaller animals (below 10 cm) showed flight responses. Animals larger than 15 cm in length were tested by pipetting "sea-star water" over the foot and epipodium; no reaction was displayed to this water or to sea water which had not been in contact with sea stars. A total of 66 animals were tested.

##### Responses to Contact

Contact with the tube feet of *Pisaster ochraceus* resulted in the same types of responses with *Haliotis rufescens* as observed with *H. assimilis*. However, there were several differences. While the response pattern began with the extension of the cephalic tentacles upon contact, touching the epipodial tentacles with the tube feet elicited a response resembling the mantle response of *Diodora aspera*, in which the mantle moves up over the shell (MARGOLIN, 1964a); in the case of the abalone the epipodium was extended up over the shell margin toward the medial line. Stimulation of the left lateral epipodial tentacles resulted in an extension of the left epipodial margin and of the right margin when the right lateral tentacles were touched. Stimulation of the posterior epipodial tentacles produced a strong reaction extending over the entire posterior area. Plate 50, Figure 4 shows *H. rufescens* exhibiting this last

response when stimulated by *Pycnopodia helianthoides*. The epipodium was withdrawn soon after contact with the epipodial tentacles ceased. This last response differs from the response observed when the posterior respiratory tentacle was touched by tube feet; in this case the epipodium was strongly extended up over the shell toward the respiratory pores. The response was rapid and the epipodium remained covering the shell for a period of time without further stimulation. The same result could be obtained by introducing extended tube feet into the posterior pore. Stimulation of the anterior respiratory tentacle or pore did not produce the same results; a slight movement of the anterior epipodium was seen but it did not match the former reaction in strength or time. Stimulation of the cephalic tentacles produced a recoil response, and no movement of the epipodium. Plate 50, Figure 5 shows the response when the posterior respiratory tentacle was touched by the tube feet of either *Pisaster ochraceus* or *Pycnopodia helianthoides*. This response is much more pronounced than the stimulation of the left lateral epipodial tentacles.

The flight pattern also differed from that of *Haliotis assimilis* in that *H. rufescens*, when touched by the tube feet of *Pisaster ochraceus*, exhibited shell twisting of a violent nature before flight. Flight responses when begun resembled those of *H. assimilis* with *Pycnopodia helianthoides* except that the responses of mucus emission and climbing did not result unless additional stimulation with the tube feet was made during flight. Touching either the foot or the epipodium of *H. rufescens* with tube feet gave no response; the tube feet withdrew from the exposed surfaces. Figure 2, Diagram c illustrates the responses of *H. rufescens* when contacted with the tube feet. This diagram shows clearly a correlation between the increasing size of the abalone and a tolerance to contact with the tube feet of the star. Animals in the 3 mm to 5 cm range showed reactions from 5 to 10 in strength. Specimens in the 5 cm to 10 cm range had mixed responses, about 50% responding strongly (5-10 in strength) while the others responded weakly (5-0). Abalones of 10 cm to 15 cm sizes gave weak responses, from 0 to 4 in strength, while animals above 15 cm in size exhibited very weak (3) or no response at all. Animals above 10 cm in the majority of cases clamped down at the initial stimulation (Plate 50, Figure 6) with shell twisting following continued stimu-

#### Explanation of Plate 51

##### RESPONSES TO DIFFUSED SUBSTANCES (*Haliotis assimilis* WITH *Pycnopodia helianthoides*)

Figure 7: Experimental tray  
Figure 8: Start.

Figure 9: Cephalic tentacles appear.  
Figure 10: Anterior locomotion.

Figure 11: Turning away.  
Figure 12: Flight response.



Figure 7

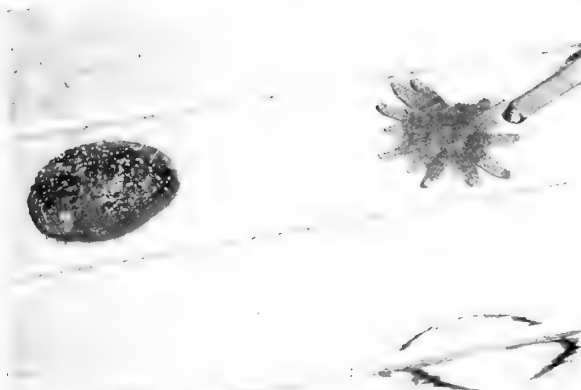


Figure 8

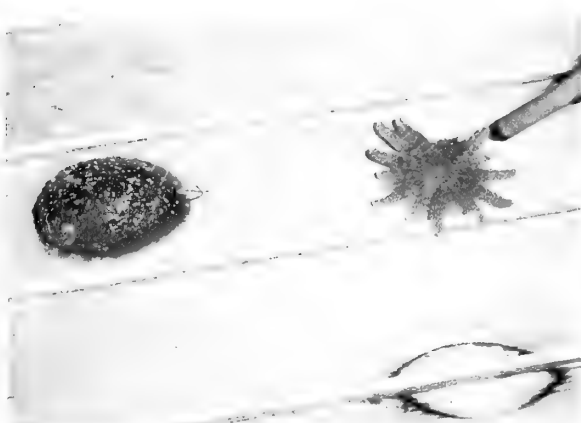


Figure 9

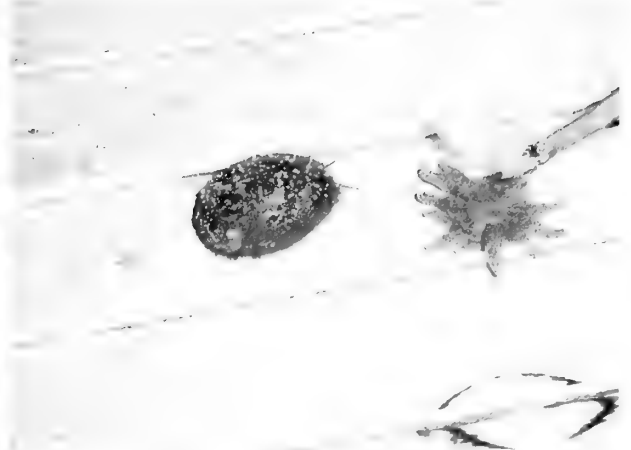


Figure 10

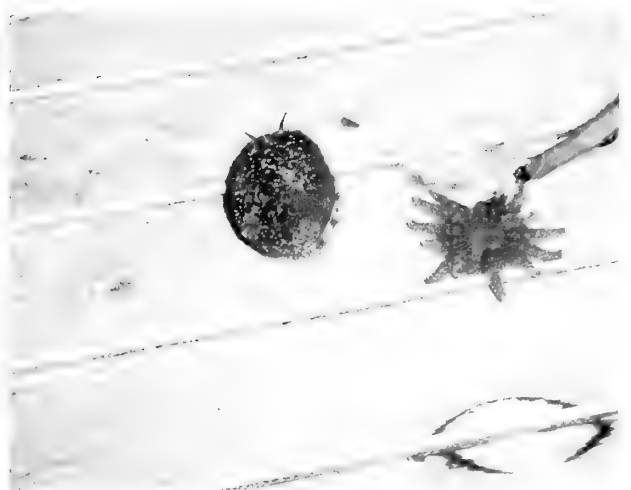


Figure 11



Figure 12





lations. *Haliotis rufescens* did not give a pushing reaction of the shell against the star. The primary source of stimulation was the tube feet. *Haliotis rufescens* displayed little response to the aboral epidermis. A star was allowed to fasten securely to the tray and then was removed, leaving several large patches of tube feet. These were pipetted into a baking dish (8"x8"x2") containing 5 small abalones (4 to 7 cm). Within 10-17 seconds all animals extended their tentacles, began violent shell twistings and within 30 seconds all had rapidly crawled out of the dish and were moving away on the tray bottom. One individual, which had extended the epipodium up over the shell, trapping several tube feet under the reflected epipodium, almost writhed out of its shell as a result. A jet of water flushed out the tube feet and the abalone rapidly crawled out of the dish and away down the tray, twisting its shell, emitting mucus and still writhing as it fled. "Sea-star water" from *Pisaster ochraceus* pipetted over the tentacles of the abalone gave very weak reactions. Tentacle activity, clamping down and shell movement back and forth were observed in the larger animals; smaller (1 to 10 cm) specimens usually gave a flight response. None of the animals exhibited an epipodial covering response. Eleven specimens of *H. rufescens* (size range 7 to 11 cm) were tested in our laboratory with *Pisaster ochraceus*. The first 4 of this series had been giving 6-7 strength responses to contact with the tube feet of non-feeding sea stars. A star that had been feeding on *Mytilus californianus* was used and the abalone gave a response strength of 9. Ten other abalones were tested with the feeding stars and all gave responses of 8-9 strength. Eleven untested abalones of the same species and size were tested with non-feeding stars; all gave responses to tube feet contact below 7 in strength. *Haliotis rufescens* showed a decrease in the strength of reaction directly proportional to time. After 6-8 stimulations with tube feet the abalone clamped down or extended the epipodium over the shell and remained quiet. Stimulation with glass, metal and wooden probes produced a clamping down response, but no movement.

#### RESPONSES OF *Haliotis rufescens* to *Pycnopodia helianthoides*

##### Stream Responses

*Haliotis rufescens* showed greater sensitivity in the stream experiments when *Pycnopodia helianthoides* was used than *Pisaster ochraceus*. Time lags before responses ranged from 30 seconds to 4 minutes and more animals went from shell twisting responses into flight responses than were noted with *Pisaster ochraceus*. Larger animals (above 10 cm in shell length) displayed no reaction or very little

reaction to a stream. Animals above 15 cm were tested by pouring "sea-star water" from *Pycnopodia helianthoides* over the tentacles; aside from slight tentacle and epipodial activity there were no significant responses. Abalones below 10 cm in size were the only ones displaying any responses.

##### Responses to Contact

Contact responses with *Pycnopodia helianthoides* resulted in tentacle activity, epipodial covering movement, shell twisting and flight responses in a typical pattern. Abalones above 12 cm in length did not respond. Figure 2, Diagram d shows the flight response strength compared with size. As in Diagram b, animals above 10 cm in size showed mixed responses, with 6 animals responding above 5 in strength and 9 showing weak (below 5) or no response. All animals below 10 cm, however, gave responses above 5, with over 50% of these above 8 in strength, indicating again the tendency of the smaller abalones to exhibit flight responses more readily than the larger ones. No significant response was noted when the abalones were stimulated by probes, fingers or empty shells.

##### Responses to Mucus

*Haliotis assimilis* sometimes liberated quantities of a transparent, viscid mucus from the respiratory pores when stimulated by *Pycnopodia helianthoides* or upon repeated stimulation by *Pisaster ochraceus*. *Haliotis rufescens* liberated a like mucus when repeatedly touched by the tube feet of either star. Such mucus emission was not observed in abalones over 15 cm in length in either species. Some animals immediately emitted mucus when dropped into a tray of "sea-star water" (using *Pycnopodia helianthoides* as a stimulus). Male abalones ejected sperm with the mucus, imparting a cloudy appearance to the mucus. When not mixed with sperm or mantle cavity debris the mucus is quite transparent and difficult to see in the water. Plate 50, Figure 2 shows *H. assimilis* liberating mucus after stimulation with *Pycnopodia helianthoides*. Such mucus was sometimes emitted in quantities to saturate the water in the tray. As previously noted, fatigue trials had to be terminated because dermal branchiae of the star were coated with the mucus. Mucus experiments were limited by time. However, several trials showed interesting results. It was possible to obtain mucus which was little mixed with sea water from a specimen of *H. assimilis*. This mucus was poured into a dish of sea water with two untested *H. assimilis*. Within 47 seconds both tentacle and epipodial activity were observed, and after 1½ minutes the animals exhibited flight responses. This same mucus poured into a dish with *H. rufescens* caused some shifting

Table 1  
SUMMARY OF RESPONSES

Asteroids		Abalones	
		<i>Haliotis assimilis</i>	<i>Haliotis rufescens</i>
Responses to Water Stream across Oral Surface of Star			
<i>Pycnopodia helianthoides</i>	Flight (within 1-6 minutes)	Turning away (within 48 to 60 seconds); flight.	
<i>Pisaster ochraceus</i>	Flight (within 25 seconds)	Turning away (within 48 sec. to 5 min.); flight.	
Responses to Contact with Star's Aboral Epidermis			
<i>Pycnopodia helianthoides</i>	Flight.	Flight.	
<i>Pisaster ochraceus</i>	No response.	No response.	
Responses to Contact with Star's Tube Feet			
<i>Pycnopodia helianthoides</i>	Epipodium extends, swells, stiffens; flight; shell whirling during flight.	Epipodium partly covers shell; shell whirling; flight.	
<i>Pisaster ochraceus</i>	Epipodium extends, swells, stiffens; flight; shell whirling during flight.	Epipodium partly covers shell; shell whirling; flight.	

of the shell, and tentacle activity, but no other significant responses. Mucus from *H. rufescens*, when poured into dishes with untested *H. rufescens* caused slight epipodial covering of the shell and in two cases slow flight responses. This mucus when tried with *H. assimilis* caused only tentacle activity and shell shifting.

## DISCUSSION

Responses observed in these experiments are termed flight responses rather than escape responses, since no field data are available to indicate that a predator-prey relationship exists between abalone and asteroids. The ecological significance of these laboratory observations cannot be evaluated without field information. Conversations with commercial abalone divers, skin and SCUBA divers, however, appear to confirm FEDER's (1963) belief that *Pisaster ochraceus* is not an active predator of *Haliotis rufescens*. Such divers also insist that very few sightings have been made of *Pycnopodia helianthoides* preying on either *H. rufescens* or *H. assimilis*. Commercial divers report that certain localities, e. g., Santa Barbara Channel Islands, abound in *Pycnopodia helianthoides* to the extent that they are a bother when gathering abalone, yet no predation

was noted. No reliable information is available regarding the possible predation upon *Haliotis assimilis* by *Pycnopodia helianthoides*.

There are several responses which might seem to be of survival value to the abalone. Size alone may be of value. Text figure 2, with the exception of the responses of *Haliotis assimilis* to *Pycnopodia helianthoides*, indicates that the larger animals have a higher toleration to contact with the asteroid. Specimens of *H. rufescens* above 12 cm showed little or no response. The clamping down of the larger abalones is of obvious value. Tube feet of either species of star showed an inability to attach to the reflected epipodial surface of *H. rufescens*, in fact, withdrew on contact. MARGOLIN (1964) indicated the same effect with *Diodora aspera* and *Pisaster ochraceus*. *Haliotis assimilis*, not utilizing this epipodial response, relied on flight to avoid the irritating contact with both species of stars. The twisting of the shell and pushing reaction would seem to be of value in breaking the hold of the asteroid's tube feet. BENNETT (1927) reports experiments with *H. iris* and *H. australis* and *Coscinastris calamaria* where the abalone was successful in dislodging the star by twisting the shell. It is still not clear (FEDER, 1963) why *Pisaster ochraceus* does not insert its stomach into the respiratory pores. The whirling of the shell would seem to dissuade

the star from attempting such a procedure. MARGOLIN (1966) reports that *Pycnopodia helianthoides* is unable to extend its stomach beyond 10 mm; a longer extension would be required to successfully digest body parts of the abalone through the pores alone. While flight and mucus emission seem to have a value in laboratory situations it is hardly feasible to suggest their effectiveness in the field.

The presence of a substance liberated by the asteroids which in turn stimulates gastropods is definitely indicated by the stream and "sea-star water" experiments. MARGOLIN (1964) has shown that the substance from *Pisaster ochraceus* is heat-labile and does not dialyze. FEDER & LASKER (1964) further state that the active material is linked to proteins in the tube feet epidermis and that extracts of it are colloidal in water, extremely stable when dry and are not affected by light, heat (to 60° C) and air. FEDER & LASKER (*loc. cit.*) also found that strong salt solutions, distilled water or water drawn from the oral area of the asteroid could induce responses in gastropods.

No attempts were made to analyze the exudate of *Pycnopodia helianthoides*. As responses were elicited from both the tube feet and the aboral epidermis the site of production is uncertain. Responses were of equal strength upon stimulation with normal tube feet, aboral epidermis, ruptured tube feet, water from the oral area, and water from the aboral epidermis. The extremely rapid reaction to diffused substances displayed by *Haliotis assimilis*, the very sharp recoil of cephalic and epipodial tentacles upon contact with tube feet or aboral epidermis by the same species of abalone and the strong responses to "sea-star water" all suggest that the substance from *Pycnopodia helianthoides* is a major irritant. The reason for the greater sensitivity of *H. assimilis* to *Pycnopodia helianthoides* as compared with that of *H. rufescens* may be a more highly developed sensory epithelium. *Pycnopodia helianthoides* induces responses of a flight nature in a variety of animals: gastropods (intertidal and subtidal); ophiuroids; echinoids; holothuroids; nudibranchs of the dorid group; pelecypods; and cephalopods. Investigations as to the nature and mechanisms of these responses and the nature of both the exudate from the asteroids and the mucus liberated by the abalones are being pursued.

## SUMMARY

Responses of *Haliotis assimilis* and *H. rufescens* were observed when tested with the forcipulate asteroids *Pisaster ochraceus* and *Pycnopodia helianthoides*. Observations were made with 146 abalones and 13 sea stars. Responses were elicited from both species of abalone either through

mechanical contact with the tube feet and aboral epidermis or by exposure to seawater-soluble substances liberated by the stars. Responses of *H. assimilis* to either species of star consisted of: tentacle activity; stiffening and swelling of the epipodium; flight at several times normal locomotion rate; violent whirling of the shell through an arc of 180°; emission of a viscid mucus from the respiratory pores; and climbing up the sides and out of the experimental tray. *Haliotis rufescens* exhibited these same responses with the following difference: the epipodium was extended up over the shell surface, preventing the tube feet of the star from fastening on it. Responses were more pronounced to mechanical contact than to diffused substances. Trials with the mucus from stimulated abalones indicated that it, too, had an effect on other abalones, causing either a flight response or irritation, depending on the species tested. Differing degrees of sensitivity were noted in the cephalic, epipodial, and respiratory tentacles of the abalones. *Haliotis assimilis* proved the more sensitive of the abalones, in time of response, contact threshold, and duration of stimulation. *Pycnopodia helianthoides* caused stronger responses than *Pisaster ochraceus* with both species of abalone. *Haliotis rufescens* exhibited fatigue after several stimulations; *H. assimilis* did not show fatigue within the limits of the experiment.

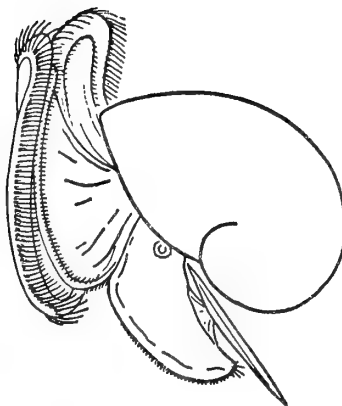
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# Length, Breadth, and Dentition in Living Cowries

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(1 Diagram)

THE PRESENT PAPER should be regarded as a continuation of the paper on "The size of ninety-five thousand cowries" (SCHILDER & SCHILDER, 1966): it is an enlargement, as in addition to the length of the shells now also their breadth and the number of labial and columellar teeth have been calculated; and it is at the same time also a restriction, as the median and the limits of usual variation have been indicated only, while the observed accidental extremes (depending on the number of examined specimens) have been omitted. The total number of specimens examined rose to 100 023.

Therefore, in the present list the nomenclature and the arrangement of 208 species and prospecies follow as closely as possible the paper cited above and newest changes in naming (SCHILDER, 1966 b) and placing of the higher taxa (SCHILDER, 1966 a) have been disregarded.

A previous paper (SCHILDER, 1939) on the average length, breadth, and relative number of teeth (calculated for hypothetical shells of 25 mm length) should be cancelled, as it refers to about half as many specimens (60 000) only.

The following list contains these eight columns:

Name of the *Genus*, *species* or - *prospecies* respectively;

n = number of specimens examined;

L = length in millimeters;

BL = relative breadth in per cent of length;

LT = absolute number of labial teeth;

CT = absolute number of columellar teeth (the anterior terminal ridges excluded);

lt = closeness of labial teeth, and

ct = closeness of columellar teeth, both according to the tables given by SCHILDER, 1958.

In each column

the two marginal numbers indicate the limits of usual variation, *i. e.* the variation of two thirds of specimens approaching the mean (see SCHILDER & SCHILDER, 1966, p. 209);

the central figure (placed in parentheses) indicates the median (see *ibid.*, p. 208).

In species the number of specimens of which is small, the limits of the standard deviation ( $\sigma$ ) and the arithmetic mean have been calculated instead; such figures are presented in *italics* instead of being placed in [ ] as in SCHILDER & SCHILDER, 1966.

Name	n	L	BL	LT	CT	lt	ct
<i>Bernaya</i>							
<i>teulerei</i> (CAZENAVETTE, 1846)	36	44( 48 )52	69(72)74	15(16)18	—(—)—	g( h )i	—( — )—
<i>fultoni</i> (SOWERBY, 1903)	9	55( <i>58</i> )62	63( <i>66</i> )68	19(20)21	11( <i>12</i> )13	i( i )k	e( f )g
<i>catei</i> SCHILDER, 1963	1	—( 76 )—	—(65)—	—(23)—	—(16)—	—( k )—	—( i )—
<i>Zoila</i>							
<i>decipiens</i> (SMITH, 1880)	60	49( 53 )57	65(67)69	20(22)23	16(17)18	k( l )m	k( l )m
<i>venusta</i> (SOWERBY, 1846)	38	58( 66 )78	62(64)66	21(24)27	18(20)22	k( l )n	h( i )k
<i>thersites</i> (GASKOIN, 1849)	104	66( 72 )76	66(69)71	23(25)27	18(19)20	l(m)n	k( l )l
<i>friendii</i> (GRAY, 1831)	89	57( 73 )86	52(58)64	24(26)28	18(20)22	l(m)n	k( l )m
<i>marginata</i> (GASKOIN, 1849)	8	50( <i>55</i> )59	57( <i>60</i> )64	26( <i>28</i> )29	18( <i>20</i> )23	o( p )p	l( n )p
<i>rosselli</i> (COTTON, 1948)	5	47( <i>50</i> )58	66( <i>69</i> )72	24( <i>28</i> )31	19( <i>23</i> )26	n( p )r	n( p )r
<i>Siphocypraea</i>							
<i>mus</i> (LINNAEUS, 1758)	120	36( 40 )46	68(71)74	16(17)19	11(11)12	h( i )l	f( f )g

Name	n	L	BL	LT	CT	lt	ct
<i>Trona</i>							
<i>stercoraria</i> (LINNAEUS, 1758)	720	41( 52 )65	63(67)72	30(32)34	24(26)27	r( s )u	q( s )t
<i>Macrocypraea</i>							
<i>zebra</i> (LINNAEUS, 1758)	213	49( 72 )90	51(53)56	33(36)39	30(32)34	r( s )u	s( u )v
<i>cervus</i> (LINNAEUS, 1771)	61	78(104)122	53(57)60	39(42)44	33(36)39	r( s )t	r( t )u
— <i>cervinetta</i> (KIENER, 1843)	146	51( 64 )79	48(50)53	31(33)35	26(27)29	q( r )s	q( r )s
<i>Mauritia</i>							
<i>valentia</i> (PERRY, 1811)	6	<b>84( 92 )100</b>	<b>70(71)73</b>	<b>37(39)41</b>	<b>38(40)42</b>	r( s )t	x( x )y
<i>mappa</i> (LINNAEUS, 1758)	345	58( 71 )78	60(63)67	34(37)39	31(33)35	r( t )u	t( u )w
<i>eglantina</i> (DUCLOS, 1833)	1285	44( 51 )58	56(58)60	32(34)36	31(34)36	t( u )v	s( u )v
<i>histrio</i> (GMELIN, 1791)	376	50( 54 )63	59(61)65	31(33)35	25(27)29	r( t )u	r( s )u
<i>grayana</i> SCHILDER, 1930	306	36( 45 )61	58(61)64	30(32)35	26(28)30	s( u )w	t( v )x
<i>arabica</i> (LINNAEUS, 1758)	2645	37( 44 )56	60(64)68	27(28)31	21(23)26	q( r )t	p( r )t
— <i>immanis</i> SCHILDER & SCHILDER, 1939	222	66( 74 )83	60(62)65	31(33)35	27(29)31	p( q )r	q( r )t
<i>maculifera</i> SCHILDER, 1932	511	47( 59 )70	64(67)71	29(31)32	23(25)27	p( q )r	p( q )s
<i>depressa</i> (GRAY, 1824)	300	30( 36 )40	69(72)76	22(24)26	17(18)20	o( p )r	m( n )p
<i>mauritiana</i> (LINNAEUS, 1758)	951	62( 78 )90	66(70)73	22(24)27	18(20)22	k( l )n	k( l )n
<i>scurra</i> (GMELIN, 1791)	76	32( 36 )44	53(55)58	37(39)42	26(28)30	A( C )E	v( x )z
— <i>indica</i> (GMELIN, 1791)	525	30( 39 )45	49(52)55	40(42)45	29(31)33	B( D )F	x( z )B
<i>Talparia</i>							
<i>talpa</i> (LINNAEUS, 1758)	654	52( 62 )74	51(53)55	42(46)49	35(37)40	x( A )C	x( z )C
<i>exusta</i> (SOWERBY, 1832)	36	61( 69 )76	53(56)57	54(59)62	50(52)55	D( G )J	H( K )M
<i>Cypraea</i>							
<i>tigris</i> LINNAEUS, 1758	1513	67( 81 )103	67(70)73	23(25)26	21(22)24	k( l )m	l( m )o
<i>pantherina</i> SOLANDER, 1786	621	56( 64 )74	58(61)63	24(26)28	26(28)30	m( n )o	q( s )t
<i>Lyncina</i>							
<i>aurantium</i> (GMELIN, 1791)	303	90( 96 )101	64(66)68	36(38)40	32(34)36	q( r )s	r( t )v
<i>broderipii</i> (SOWERBY, 1832)	6	<b>68( 78 )88</b>	<b>63(66)68</b>	<b>25(28)31</b>	<b>27(30)33</b>	l( o )r	q( s )t
<i>nivosa</i> (BRODERIP, 1827)	22	41( 51 )60	59(61)64	26(28)30	25(26)27	o( q )r	r( s )t
<i>leucodon</i> (BRODERIP, 1828)	3	<b>77( 82 )83</b>	<b>65(68)71</b>	<b>25(25)26</b>	<b>21(22)23</b>	l( l )m	l( m )n
<i>porteri</i> (CATE, 1966)	1	—( 47 )—	—(74)—	—(30)—	—(29)—	—( s )—	—( v )—
<i>argus</i> (LINNAEUS, 1758)	272	59( 70 )83	50(52)55	35(37)39	31(33)35	s( t )u	t( v )w
<i>lynx</i> (LINNAEUS, 1758)	2991	30( 35 )41	57(60)63	22(23)25	18(19)20	o( p )q	n( o )q
<i>vitellus</i> (LINNAEUS, 1758)	1170	36( 44 )54	61(63)66	24(26)27	10(21)23	o( p )q	o( p )r
<i>camelopardalis</i> (PERRY, 1811)	79	46( 54 )64	58(61)64	25(26)28	25(27)29	n( o )p	r( t )u
<i>reevei</i> (SOWERBY, 1832)	53	29( 34 )39	60(64)66	30(32)34	23(25)27	v( w )y	t( v )x
<i>ventriculus</i> (LAMARCK, 1810)	121	41( 49 )57	64(67)69	22(24)26	19(21)22	m( n )o	n( o )p
<i>schilderorum</i> (IREDALE, 1939)	139	27( 30 )34	64(69)73	26(28)29	21(22)24	s( u )v	s( t )v
— <i>kuroharai</i> (KURODA & HABE, 1961)	4	<b>41( 44 )47</b>	<b>67(69)71</b>	<b>27(28)28</b>	<b>26(27)28</b>	q( r )r	u( v )w
<i>sulcidentata</i> (GRAY, 1824)	135	32( 39 )48	68(72)76	24(26)27	20(21)23	o( q )r	o( q )r
<i>carneola</i> (LINNAEUS, 1758)	3538	24( 28 )34	58(61)65	23(25)26	19(20)22	q( s )t	p( r )t
— <i>titan</i> SCHILDER & SCHILDER, 1962	156	43( 49 )56	55(57)60	27(29)31	23(24)26	p( r )s	q( r )s
— <i>leviathan</i> (SCHILDER & SCHILDER, 1937)	59	63( 72 )86	55(58)62	32(36)39	27(30)32	q( s )u	q( s )u
<i>Chelycypraea</i>							
<i>testudinaria</i> (LINNAEUS, 1758)	178	86(103)123	49(51)52	45(49)52	38(42)45	u( w )x	v( x )y

Name	n	L	BL	LT	CT	lt	ct
<i>Luria</i>							
<i>tessellata</i> (SWAINSON, 1822)	98	23( 27 )32	68(71)74	25(27)29	20(22)25	t(u)w	r(u)x
<i>pulchra</i> (GRAY, 1828)	91	35( 41 )54	54(56)58	36(39)42	31(34)37	y(A)C	z(B)E
<i>isabella</i> (LINNAEUS, 1758)	3979	20( 25 )29	52(55)57	28(30)32	25(27)29	B(D)G	y(A)C
– <i>mexicana</i> (STEARNS, 1893)	166	30( 36 )40	49(53)58	35(38)40	29(32)35	y(B)C	y(B)E
<i>cinerea</i> (GMELIN, 1791)	625	21( 25 )30	60(63)67	23(24)26	16(18)20	r(s)u	n(p)r
<i>lurida</i> (LINNAEUS, 1758)	628	23( 33 )44	56(59)62	22(23)25	17(18)19	o(p)r	m(o)q
<i>Pustularia</i>							
<i>mariae</i> SCHILDER, 1927	108	11( 13 )16	65(66)70	31(34)36	21(23)26	K(N)Q	A(D)H
<i>globulus</i> (LINNAEUS, 1758)	395	12( 16 )19	60(62)65	27(29)31	18(20)22	A(D)F	t(v)y
<i>margarita</i> (DILLWYN, 1817)	381	11( 12 )15	58(61)65	26(28)30	17(19)21	D(F)J	v(y)A
<i>cicercula</i> (LINNAEUS, 1758)	445	14( 16 )19	59(62)66	26(28)31	19(21)22	z(C)F	u(x)z
<i>olowaluensis</i> (BURGESS MS.)	7	12( 13 )14	60(63)65	21(23)25	17(18)18	w(y)A	r(u)w
<i>bistrinotata</i> SCHILDER & SCHILDER, 1937	503	13( 15 )18	60(62)65	25(27)29	16(18)20	y(B)D	r(t)w
<i>childreni</i> (GRAY, 1825)	176	14( 17 )21	62(67)69	30(32)34	20(22)23	D(G)J	v(y)A
<i>Propustularia</i>							
<i>surinamensis</i> (PERRY, 1811)	33	28( 31 )35	58(61)63	20(23)25	16(18)20	n(q)r	m(o)q
<i>Monetaria</i>							
<i>annulus</i> (LINNAEUS, 1758)	10484	16( 19 )22	68(72)76	11(12)13	10(11)11	f(g)h	f(g)h
– <i>obelata</i> (LAMARCK, 1810)	756	14( 16 )21	64(68)73	11(12)12	9( 9 )10	f(g)g	e(f)g
<i>moneta</i> (LINNAEUS, 1758)	5306	16( 20 )25	67(73)78	11(12)13	10(11)12	f(g)h	g(h)i
<i>Naria</i>							
<i>irrorata</i> (GRAY, 1828)	276	10( 11 )13	54(57)60	18(20)22	15(17)18	r(u)w	s(v)w
<i>Erosaria</i>							
<i>dillwyni</i> (SCHILDER, 1922)	62	11( 12 )13	58(60)62	29(31)33	18(20)22	H(M)O	w(z)C
<i>beckii</i> (GASKOIN, 1836)	71	8( 10 )11	57(58)61	16(18)21	15(17)19	s(t)x	t(w)z
<i>macandrewi</i> (SOWERBY, 1870)	43	12( 14 )17	54(55)57	18(19)20	17(19)21	q(r)t	t(v)y
<i>labrolineata</i> (GASKOIN, 1849)	1152	12( 14 )18	58(60)63	14(16)17	14(15)16	l(n)o	m(o)r
<i>cernica</i> (SOWERBY, 1870)	48	19( 22 )25	63(69)73	18(19)20	15(17)18	n(o)p	m(o)q
– <i>tomlini</i> SCHILDER, 1930	62	12( 18 )24	60(63)68	17(18)20	15(16)17	n(o)q	n(o)q
– <i>ogasawarensis</i> SCHILDER, 1944	34	18( 22 )31	60(64)71	18(19)21	16(17)18	n(o)q	n(o)q
<i>citrina</i> (GRAY, 1825)	56	19( 21 )25	60(63)68	19(20)21	17(19)20	o(p)r	p(q)t
<i>gangranosa</i> (DILLWYN, 1817)	1261	15( 18 )21	58(61)65	18(19)21	15(17)18	o(p)r	o(q)s
<i>boivini</i> (KIENER, 1843)	1379	19( 22 )25	60(62)66	18(19)20	14(16)17	n(o)p	l(n)p
– <i>ostergaardi</i> (DALL, 1921)	16	15( 19 )21	64(69)73	18(20)22	14(15)17	o(q)s	l(n)q
<i>helvola</i> (LINNAEUS, 1758)	3083	17( 20 )23	64(68)74	16(17)19	13(14)15	l(m)o	k(l)n
<i>caputserpentis</i> (LINNAEUS, 1758)	3574	25( 29 )32	70(74)80	16(17)18	12(13)14	i(k)l	h(i)k
<i>caputdraconis</i> (MELVILL, 1888)	141	25( 29 )33	67(70)73	15(16)17	12(13)14	h(i)k	h(i)k
<i>albuginosa</i> (GRAY, 1825)	140	19( 23 )27	56(60)65	19(21)22	16(17)19	o(q)r	n(p)r
<i>spurca</i> (LINNAEUS, 1758)	1656	21( 25 )28	61(63)66	18(20)21	14(15)17	m(o)p	k(l)n
– <i>acicularis</i> (GMELIN, 1791)	321	16( 20 )23	63(67)71	17(18)19	13(14)15	m(n)o	k(l)n
<i>poraria</i> (LINNAEUS, 1758)	680	14( 16 )18	66(69)73	17(19)21	13(14)16	o(q)s	m(n)p
<i>englerti</i> (BURGESS & SUMMERS, 1965)	3	23( 24 )24	70(72)75	18(19)20	15(16)16	m(n)o	m(n)n
<i>erosa</i> (LINNAEUS, 1758)	3417	25( 30 )35	58(62)66	17(18)19	13(14)15	k(l)m	i(k)l
– <i>nebrites</i> (MELVILL, 1888)	294	21( 26 )30	63(65)69	16(17)18	13(15)16	k(l)m	i(l)m
<i>ocellata</i> (LINNAEUS, 1758)	359	19( 24 )29	63(67)72	17(18)19	14(15)16	l(m)n	k(l)n
<i>marginalis</i> (DILLWYN, 1827)	172	22( 26 )30	63(66)70	18(20)22	20(22)24	m(o)q	o(p)s
<i>miliaris</i> (GMELIN, 1791)	538	25( 32 )37	60(63)66	17(17)18	13(14)15	k(k)l	h(i)k

Name	n	L	BL	LT	CT	lt	ct
<i>Erosaria</i> (cont.)							
– <i>eburnea</i> (BARNES, 1824)	155	33( 38 )44	59(61)63	18(19)20	14(15)16	k( l )m	i( k )l
– <i>lamarckii</i> (GRAY, 1825)	509	29( 33 )38	63(67)70	17(18)19	14(15)16	k( l )m	i( k )l
– – <i>redimita</i> (MELVILL, 1888)	170	27( 30 )35	63(66)70	17(18)19	13(14)16	k( l )m	i( k )m
<i>turdus</i> (LAMARCK, 1810)	922	24( 30 )38	64(69)73	16(17)18	14(15)17	i( k )l	k( l )n
<i>guttata</i> (GMELIN, 1791)	18	53( 62 )66	58(60)64	22(25)28	18(20)22	l(m)o	l(m)o
<i>Staphylaea</i>							
<i>staphylaea</i> (LINNAEUS, 1758)	1157	11( 15 )19	59(62)65	19(20)22	15(17)18	q( s )v	p( r )t
<i>limacina</i> (LAMARCK, 1810)	387	19( 24 )28	56(58)60	20(22)24	16(18)21	o( q )s	n( q )t
<i>semiplota</i> (MIGHELS, 1845)	227	11( 14 )20	57(60)65	17(19)20	15(16)17	p( r )t	p( r )t
<i>Nuclearia</i>							
<i>nucleus</i> (LINNAEUS, 1758)	1177	16( 19 )23	59(62)65	23(24)26	15(16)17	t( v )x	n( o )q
– <i>granulata</i> (PEASE, 1862)	140	22( 27 )31	66(69)73	21(23)25	18(20)21	p( r )s	o( r )s
– <i>cassiaui</i> (BURGESS, 1965)	11	23( 26 )28	64(69)73	20(21)22	13(15)16	o( p )q	k( l )m
<i>Schilderia</i>							
<i>achatidea</i> (SOWERBY, 1837)	125	27( 33 )38	61(63)65	27(29)30	23(25)27	t( u )v	p( r )s
<i>langfordi</i> (KURODA, 1938)	5	50( 54 )58	61(63)68	27(29)30	24(25)26	p( q )r	q( r )s
– <i>moretonensis</i> SCHILDER, 1965	4	54( 59 )65	58(60)63	27(29)31	25(26)27	o( p )r	q( r )s
<i>hirasei</i> (ROBERTS, 1913)	9	46( 50 )54	62(64)66	27(28)29	23(25)28	o( q )r	q( s )t
<i>queenslandica</i> SCHILDER, 1966	1	—( 57 )—	—(61)—	—(33)—	—(37)—	—( s )—	—( A )—
<i>teramachii</i> (KURODA, 1938)	6	60( 67 )74	59(61)64	30(32)34	26(28)29	p( q )r	p( r )t
<i>Zonaria</i>							
<i>zonaria</i> (GMELIN, 1791)	164	24( 28 )33	60(63)66	19(20)21	14(16)18	m( n )o	k( m )o
<i>picta</i> (GRAY, 1824)	192	24( 27 )31	55(59)63	17(19)21	16(18)20	l( m )o	n( p )r
<i>sanguinolenta</i> (GMELIN, 1791)	37	19( 21 )24	57(59)61	19(20)22	14(15)17	o( p )r	m( n )p
<i>pyrum</i> (GMELIN, 1791)	322	28( 33 )38	57(59)61	18(20)22	14(15)16	l( n )o	i( k )l
– <i>petitiana</i> (CROSSE, 1872)	33	20( 25 )35	59(61)65	17(19)20	13(15)17	l( n )o	i( l )n
<i>annettae</i> (DALL, 1909)	112	29( 35 )43	55(57)61	20(21)22	15(17)19	m( n )o	k( m )o
– <i>aequinoctialis</i> SCHILDER, 1933	13	38( 40 )45	57(61)63	18(19)20	13(14)16	k( l )l	g( i )l
<i>spadicea</i> (SWAINSON, 1823)	120	38( 44 )50	57(59)60	21(23)25	19(20)21	m( n )o	n( o )p
<i>robertsi</i> (HIDALGO, 1906)	117	21( 24 )28	64(68)71	17(18)19	12(13)14	l( m )n	h( i )k
<i>nigropunctata</i> (GRAY, 1828)	224	22( 26 )32	54(57)58	19(21)22	15(16)18	n( p )q	l( m )o
<i>arabacula</i> (LAMARCK, 1810)	119	21( 26 )30	61(66)69	21(22)24	15(16)17	p( q )s	l( m )n
<i>Cypraeovula</i>							
<i>fuscrobura</i> (SHAW, 1909)	34	33( 37 )42	62(65)73	18(20)22	18(19)21	k( m )o	n( o )q
<i>fuscudentata</i> (GRAY, 1825)	245	28( 31 )34	56(58)60	16(17)18	13(14)16	i( k )l	i( k )m
<i>cohenae</i> (BURGESS, 1965)	2	25( 27 )29	60(60)60	16(16)17	—(—)—	k( k )k	—(—)—
<i>algoensis</i> (GRAY, 1825)	46	20( 24 )26	59(63)65	20(21)22	15(16)17	o( p )q	m( n )o
<i>edentula</i> (GRAY, 1825)	418	21( 24 )26	60(62)64	21(23)25	24(28)30	p( r )t	x( C )E
<i>amphithales</i> (MELVILL, 1888)	5	26( 28 )30	58(59)60	21(23)26	21(27)33	r( s )t	t( z )G
<i>capensis</i> (GRAY, 1828)	329	29( 31 )33	57(59)61	25(26)28	38(44)47	r( s )u	L( P )T
<i>Umbilia</i>							
<i>armeniaca</i> (VERCO, 1912)	5	77( 86 )95	61(70)80	33(36)39	24(26)29	q( r )s	n( p )r
– <i>hesitata</i> (IREDALE, 1916)	135	75( 91 )100	56(58)61	34(37)39	27(29)31	p( r )s	p( q )r
<i>Notocypraea</i>							
<i>pulicaria</i> (REEVE, 1846)	82	16( 17 )19	55(57)58	23(25)26	22(23)25	v( x )y	y( A )C
<i>bicolor</i> (GASKOIN, 1849)	120	19( 21 )23	57(59)61	23(24)25	19(20)22	s( u )v	s( t )w
– <i>occidentalis</i> IREDALE, 1935	136	17( 19 )21	58(59)61	23(24)26	19(20)22	u( v )x	t( v )x
<i>piperita</i> (GRAY, 1825)	521	20( 22 )24	58(61)64	22(24)26	18(20)22	r( t )v	r( t )w
<i>angustata</i> (GMELIN, 1791)	271	23( 26 )28	65(68)70	22(24)26	18(20)21	q( s )u	p( r )t
<i>declivis</i> (SOWERBY, 1870)	37	22( 25 )27	64(66)69	23(24)26	18(20)21	r( s )u	o( r )s



Name	n	L	BL	LT	CT	lt	ct
<i>Erronea</i>							
<i>walkeri</i> (SOWERBY, 1832)	114	20( 23 )28	57(59)61	20(21)23	19(21)23	p( q )s	r( t )w
– <i>bregeriana</i> (CROSSE, 1868)	33	19( 22 )28	58(61)63	18(20)21	17(19)20	n( p )q	p( r )t
<i>pyriformis</i> (GRAY, 1824)	130	22( 25 )29	59(61)63	18(19)21	17(19)20	m( n )p	o( q )s
<i>pulchella</i> (SWAINSON, 1823)	52	35( 38 )41	54(57)59	26(28)30	21(23)24	q( s )u	q( s )t
– <i>novaebritanniae</i> SCHILDER & SCHILDER, 1937	5	23( 24 )25	55(56)57	22(24)26	19(21)22	q( t )v	r( t )v
– <i>pericalles</i> (MELVILL & STANDEN, 1904)	18	28( 31 )34	54(56)57	23(24)25	17(19)21	o( q )s	n( p )s
<i>hungerfordi</i> (SOWERBY, 1888)	22	31( 33 )36	59(62)64	22(23)24	18(20)22	o( p )q	n( p )s
– <i>coucomi</i> SCHILDER, 1964	10	28( 34 )40	56(58)61	22(25)27	19(22)24	p( q )r	p( r )t
<i>barclayi</i> (REEVE, 1837)	3	22( 24 )26	61(64)67	21(22)23	17(18)18	q( r )r	o( o )p
<i>xanthodon</i> (SOWERBY, 1832)	1146	23( 26 )29	58(60)63	20(21)22	16(17)18	o( p )q	m( n )o
<i>vredenburgi</i> SCHILDER, 1927	1596	18( 21 )24	60(62)64	19(20)21	14(15)16	o( p )q	l( n )o
<i>pallida</i> (GRAY, 1828)	720	22( 24 )26	62(64)65	17(18)19	14(15)16	l( m )n	l( m )n
<i>subviridis</i> (REEVE, 1835)	208	26( 30 )35	61(64)66	17(18)19	16(17)19	k( l )m	i( k )m
– <i>dorsalis</i> SCHILDER & SCHILDER, 1938	120	26( 30 )34	58(60)63	18(19)20	18(19)21	l( m )n	l( m )o
– <i>piscatorum</i> SCHILDER, 1965	2	30( 31 )31	60(62)63	22(22)22	15(16)17	o( p )p	l( m )n
<i>onyx</i> (LINNAEUS, 1758)	84	32( 37 )43	59(61)64	19(20)21	15(16)17	l( m )n	k( l )m
– <i>melanesiae</i> SCHILDER & SCHILDER, 1937	8	32( 39 )46	56(60)64	19(20)21	14(17)19	k( l )n	i( m )o
– <i>nymphae</i> (JAY, 1850)	40	36( 41 )45	59(60)62	19(21)22	15(16)17	l( m )n	k( l )m
– <i>adusta</i> (LAMARCK, 1810)	121	36( 41 )47	58(60)62	18(20)21	16(17)19	k( l )m	l( m )o
<i>ovum</i> (GMELIN, 1791)	575	23( 26 )30	56(58)61	15(16)17	15(16)18	i( k )l	l( m )o
<i>errones</i> (LINNAEUS, 1758)	3489	19( 23 )28	54(56)58	14(15)16	13(14)16	h( i )k	k( l )n
<i>cylindrica</i> (BORN, 1778)	203	24( 28 )33	45(48)50	15(17)19	19(21)22	i( k )m	q( s )t
– <i>sowerbyana</i> SCHILDER, 1932	121	27( 30 )34	50(51)53	18(19)20	19(20)22	l( m )n	p( r )t
<i>caurica</i> (LINNAEUS, 1758)	1503	29( 35 )41	52(55)59	16(18)19	16(18)19	i( k )l	l( n )o
<i>felina</i> (GMELIN, 1791)	353	16( 18 )21	59(62)67	14(15)16	12(13)14	i( l )m	i( k )l
– <i>listeri</i> (GRAY, 1824)	649	12( 15 )18	53(55)58	13(15)16	12(14)15	i( l )m	k( m )o
<i>Notadusta</i>							
<i>punctata</i> (LINNAEUS, 1771)	563	9( 11 )14	55(57)60	19(20)22	17(19)20	t( v )y	v( y )A
<i>rabaulensis</i> SCHILDER, 1964	7	19( 21 )23	50(52)54	20(21)23	22(23)24	o( q )s	v( x )z
<i>katsuae</i> (KURODA, 1960)	5	19( 21 )22	54(56)58	28(30)32	24(26)28	y( B )E	y( B )E
<i>martini</i> (SCHEPMAN, 1907)	12	14( 16 )17	50(52)54	20(22)23	25(27)28	s( u )v	F( H )J
<i>superstes</i> (SCHILDER, 1930)	8	17( 18 )19	52(54)55	26(28)29	28(31)33	x( z )B	H( L )O
<i>Palmadusta</i>							
<i>asellus</i> (LINNAEUS, 1758)	1626	13( 15 )17	55(59)62	17(19)20	13(14)16	o( q )r	l( o )q
<i>clandestina</i> (LINNAEUS, 1767)	1072	11( 14 )17	59(61)64	16(18)20	14(15)17	o( q )s	n( p )s
<i>artuffeli</i> (JOUSSEAUME, 1876)	134	14( 16 )18	59(61)62	17(18)20	14(16)17	o( p )r	n( p )r
<i>saualae</i> (GASKOIN, 1843)	44	20( 23 )27	53(56)58	18(19)20	16(17)18	m( o )p	n( p )q
<i>contaminata</i> (SOWERBY, 1832)	44	9( 11 )13	56(58)60	19(20)21	16(17)19	t( w )x	t( v )y
<i>lutea</i> (GMELIN, 1791)	79	15( 18 )20	55(58)60	17(19)21	15(16)17	n( p )r	n( p )r
– <i>humphreysii</i> (GRAY, 1825)	130	12( 15 )19	58(60)62	15(17)18	14(16)17	m( o )p	n( q )s
<i>ziczac</i> (LINNAEUS, 1758)	284	13( 16 )19	59(61)64	18(20)21	15(17)19	p( r )s	p( s )u
<i>diluculum</i> (REEVE, 1845)	201	17( 23 )28	60(61)64	18(19)20	16(17)18	m( n )p	n( o )q
<i>lentiginosa</i> (GRAY, 1825)	48	21( 26 )31	57(60)66	17(18)19	13(15)16	l( m )n	i( l )m
<i>Purpuradusta</i>							
<i>gracilis</i> (GASKOIN, 1849)	1688	14( 16 )19	58(60)62	16(17)18	13(14)16	m( n )p	l( n )q
<i>hammondae</i> (IREDALE, 1939)	52	12( 14 )15	58(60)62	14(15)16	14(15)16	n( p )q	o( p )r

Name	n	L	BL	LT	CT	lt	ct
<i>Purpuradusta</i> (cont.)							
– <i>raysummersi</i> SCHILDER, 1960	39	13( 15 )16	54(56)58	19(20)21	16(17)19	q( r )t	q( r )u
<i>fimbriata</i> (GMELIN, 1791)	584	11( 12 )14	55(57)59	16(17)19	15(16)18	o( p )s	q( t )w
<i>minoridens</i> (MELVILL, 1901)	1274	7( 8 ) 9	53(55)56	16(17)19	15(17)18	r( t )w	v( y )A
<i>serrulifera</i> (SCHILDER & SCHILDER, 1938)	80	7( 8 ) 9	50(52)61	19(21)22	18(19)21	x( z )B	A( C )F
<i>microdon</i> (GRAY, 1828)	239	8( 10 )12	53(55)57	20(22)24	19(20)22	w( z )B	A( B )E
<i>Blasicrura</i>							
<i>quadrinaculata</i> (GRAY, 1824)	264	17( 20 )23	49(51)54	17(19)20	17(19)21	m( o )p	p( s )u
<i>coxeni</i> (COX, 1873)	82	19( 22 )26	49(53)57	16(18)19	16(17)19	l( n )o	n( p )s
– <i>hesperina</i> SCHILDER & SUMMERS, 1963	44	15( 17 )20	49(51)53	15(16)18	15(17)18	l( m )o	o( q )s
<i>interrupta</i> (GRAY, 1824)	414	18( 20 )22	51(52)55	20(21)23	19(20)22	s( u )w	s( t )w
– <i>pallidula</i> (GASKOIN, 1849)	860	15( 16 )19	55(57)58	18(20)21	15(16)17	p( r )t	o( q )s
– <i>summersi</i> (SCHILDER, 1958)	169	14( 15 )17	53(55)57	17(18)19	11(12)14	o( p )q	i( k )n
<i>rashleighana</i> (MELVILL, 1888)	16	14( 15 )18	60(62)63	15(16)18	14(17)19	m( n )p	n( r )u
– <i>eunota</i> (TAYLOR, 1916)	32	19( 23 )26	62(67)71	17(19)20	15(16)17	l( n )o	m( n )p
– <i>latior</i> (MELVILL, 1888)	50	27( 32 )37	61(64)68	20(23)24	19(20)22	n( p )q	p( q )s
<i>teres</i> (GMELIN, 1791)	1333	21( 24 )29	52(54)57	22(24)25	21(22)25	q( s )t	t( v )y
– <i>subteres</i> (WEINKAUFF, 1881)	29	17( 21 )26	46(47)49	24(25)27	24(25)26	t( u )x	y( A )B
<i>goodallii</i> (SOWERBY, 1832)	83	9( 10 )13	54(55)59	19(21)22	16(18)19	u( x )z	u( x )z
<i>Bistolida</i>							
<i>kieneri</i> (HIDALGO, 1906)	656	11( 13 )18	55(57)60	15(16)17	12(13)15	m( o )p	l( n )p
<i>owenii</i> (SOWERBY, 1837)	118	10( 14 )16	57(60)67	15(16)17	12(13)14	m( o )p	k( l )n
<i>hirundo</i> (LINNAEUS, 1758)	821	12( 15 )17	55(59)62	19(20)22	14(16)17	q( s )u	o( q )s
<i>ursellus</i> (GMELIN, 1791)	462	9( 11 )13	59(61)63	19(20)21	15(16)18	t( v )x	r( t )w
<i>erythraeensis</i> (SOWERBY, 1837)	33	16( 19 )22	56(59)62	19(21)22	16(18)19	p( r )s	p( s )t
<i>stolidia</i> (LINNAEUS, 1758)	444	21( 24 )29	55(58)62	19(21)22	15(17)19	n( p )q	m( o )q
<i>Ovatipsa</i>							
<i>chinensis</i> (GMELIN, 1791)	348	27( 32 )38	58(61)66	16(18)18	16(17)18	i( l )l	l( n )o
– <i>tortirostris</i> (SOWERBY, 1906)	12	9( 12 )14	56(61)66	9(10)11	9(11)13	d( e )g	f( i )l
– <i>coloba</i> (MELVILL, 1888)	92	22( 26 )30	67(73)78	14(15)16	14(15)17	h( i )k	k( l )n
<i>Cribraria</i>							
<i>cribraria</i> (LINNAEUS, 1758)	641	17( 21 )26	56(58)62	16(18)20	15(17)19	l( n )p	n( p )r
<i>cribellum</i> (GASKOIN, 1849)	51	12( 14 )16	54(56)58	13(14)17	13(14)16	k( l )o	l( n )q
<i>esontropia</i> (DUCLOS, 1833)	82	17( 24 )28	56(61)66	16(17)18	14(16)18	k( l )m	l( n )p
<i>catholicorum</i> SCHILDER & SCHILDER, 1938	114	12( 14 )16	61(63)65	16(17)18	14(15)17	o( p )q	o( q )t
<i>gaskoini</i> (REEVE, 1846)	69	13( 20 )24	59(63)70	19(20)21	16(18)20	o( p )r	p( r )t
<i>cumingii</i> (SOWERBY, 1832)	73	10( 11 )14	53(56)58	23(27)30	21(23)26	z( G )L	C( F )L

## DISCUSSION

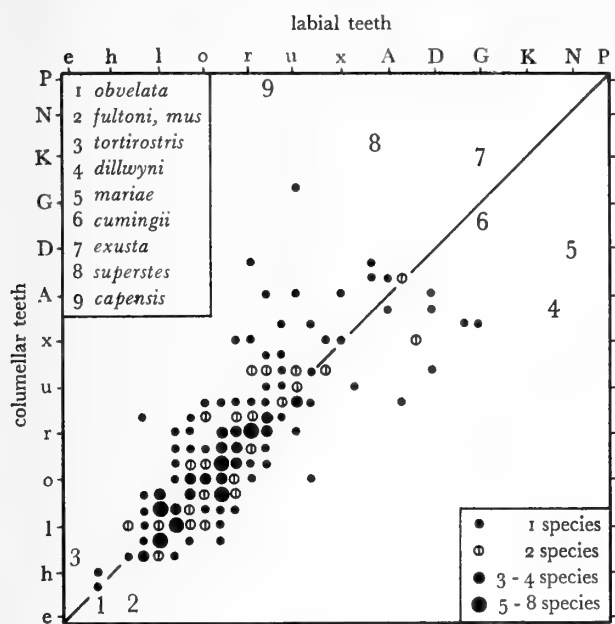
From the preceding list the following results have been obtained:

1. There is no correlation between the average length and the relative breadth among the 208 species and pro-species: among small species the slender and the broad species are distributed in about the same random way as

among large species. Thus, among rather small species of about 2 cm the relative breadth ranges from 47 (*Blasicrura teres subteres*) to 73 (*Monetaria moneta*) and among giant species of 9 to 10 cm it ranges from 51 (*Cheilocypraea testudinaria*) to 71 (*Mauritia valentia*).

2. There is, however, a general distinct correlation between the closeness of the labial and the columellar teeth, as coarse distant labial teeth generally are linked

up to coarse columellar teeth, and numerous labial teeth to numerous columellar teeth (see the Diagram, in which



the two species without columellar teeth [*Bernaya teulerei*, *Cypraeovula cohenae*] have been omitted). Thus, for instance, in the three species of *Monetaria* the teeth of both lips are coarse (class gf to gh), while in some phylogenetically separated species as *Talparia exusta*

(GK), *Pustularia mariae* (ND), and *Cribraria cumingii* (GF) the teeth of both lips are extremely fine and numerous.

3. But there is no strict correspondence of the closeness of labial teeth to that of columellar teeth, as there are many species in which the columellar teeth are distinctly more numerous than the labial teeth, and *vice versa*. Thus in *Erosaria dillwyni* (class Mz) the labial teeth are much finer than the columellar teeth, while in *Notadusta superstes* (class zL) the columellar teeth are extremely fine.

4. There is no correlation between the average length of the species and the number of teeth, a fact which justifies the method of calculating the relative closeness of dentition: coarse, distant teeth occur among small species (*Ovatipisa chinensis tortirostris*) as well as among large species (*Bernaya fultoni*), and close numerous teeth also occur among small species (*Pustularia mariae*) as well as among large cowries (*Talparia exusta*).

5. The average length and relative breadth (L/BL) in all 208 living Cypraeidae is 26/61; this formula is approached by *Erronea pyriformis* (25/61) and *E. xanthodon* (26/60). The average closeness of labial and columellar teeth (lt:ct) is p:q, represented by *Erosaria gangranosa*.

6. The following Table refers to medians (placed in parentheses in the preceding list) of 208 species and pro-species of living Cypraeidae; it indicates the median of the medians, the usual variation of the medians ( $s_1$ ,  $s_2$ ) and their extremes (mi, ma), with the names of the typical species added.

	mi	$s_1$	Med	$s_2$	ma
L:	8	16	26	52	104
	<i>Purpuradusta minoridens</i>	<i>Erosaria poraria</i>	<i>Erronea xanthodon</i>	<i>Trona stercoraria</i>	<i>Macrocypraea cervus</i>
BL:	47	56	61	67	74
	<i>Blasicrura teres subteres</i>	<i>Luria pulchra</i>	<i>Cypraea pantherina</i>	<i>Trona stercoraria</i>	<i>Erosaria caputserpentis</i>
lt:	e	l	p	u	M
	<i>Ovatipisa chinensis tortirostris</i>	<i>Mauritia mauritiana</i>	<i>Erosaria gangranosa</i>	<i>Mauritia eglantina</i>	<i>Erosaria dillwyni</i>
ct:	f	l	q	x	P
	<i>Monetaria annulus obvelata</i>	<i>Mauritia mauritiana</i>	<i>Erosaria gangranosa</i>	<i>Mauritia scurra</i>	<i>Cypraeovula capensis</i>

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## Burial Experiments on Marine Pelecypods from Tomales Bay, California

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## INTRODUCTION

BURIAL EXPERIMENTS and the after-effects on *Tellina salmonea*, *Tellina buttoni*, and *Transennella tantilla* have not as yet been reported. The harmful effects of high concentrations of particulate matter and microorganisms to filtering and feeding in bivalves have been investigated by many. For example, LOOSANOFF & ENGLE (1940, 1947), LOOSANOFF & TOMMERS (1948), CHIPMAN & HOPKINS (1954), BALLENTINE & MORTON (1956), CHIBA & OHSHIMA (1957), LOOSANOFF (1962), and ARMSTRONG (1965) have all been concerned with various aspects of this problem.

In a field study MAURER (1966) described some pelecypod-sediment associations in Tomales Bay, California. The author concluded that distribution and abundance of *Tellina buttoni* DALL, 1900, *Tellina salmonea* (CARPENTER, 1864), *Mysella tumida* (CARPENTER, 1864), and *Lyonsia californica* CONRAD, 1837 were influenced by

sediment type, while that of *Transennella tantilla* (GOULD, 1852) were not. Furthermore it was shown that the average size of *Tellina buttoni*, *Tellina salmonea*, and *Mysella tumida* was statistically associated with sediment size. No conclusions were drawn as to the biological significance of sediment to mollusks in terms of food, protection, larval sites, and certain conditions of turbidity.

In order to interpret the pelecypod-sediment relationships and to determine the importance of sediment to mollusks some filtering experiments were performed (MAURER, 1967). *Transennella tantilla* combined the highest filtering rate with the least apparent difficulty in filtering suspensions of carmine, kaolinite, and india ink particles. *Tellina salmonea* had the lowest clearing rate and had far less difficulty ingesting and digesting the suspensions than *Tellina buttoni* which had a relatively high filtering rate, but commonly became filled with particles from the suspensions. Results of these experiments suggested that sediment may represent a source of food or a certain turbidity regime.

Workers differ in opinion concerning the effects of turbidity on pelecypods. For example, TURNER (1953) noted in contrast to LOOSANOFF & ENGLE (1947) that the hard clam *Venus mercenaria* (LINNAEUS, 1758) differs from the oyster in that the former can utilize *Chlorella* and green flagellates even in concentrations so dense that the water is soupy green. However, a study of *V. mercenaria* by RICE & SMITH (1958) demonstrated that addition of silt to algal suspensions resulted in an instantaneous decrease in the filtering rate of the clam. Moreover, the clams formed large quantities of pseudofeces in the presence of high concentrations of algae, in all suspensions of *Chlorella*, and after silt was added. With this in mind, the present investigation examined the survivorship of clams buried under different amounts of clay for different periods of time. Also their rate of recovery after being placed in clean sand with rapidly flowing sea water was recorded. Results of these experiments show that mortalities and production of feces and pseudofeces were greatest in the heaviest loads of clay and that *Transennella tantilla* suffered fewer mortalities than *Tellina salmonea*, which suffered still fewer mortalities than *Tellina buttoni*.

## METHOD

The general method was as follows: *Tellina buttoni*, *T. salmonea* and *Transennella tantilla* were suspended by a screen 3.0 cm above the bottom of a 1000 ml beaker. A set of pelecypods was formed which consisted of a group of the three species each in its own beaker. Except for experiment 1 every experiment had three sets of pelecypods.

Clay was gently poured into a beaker and allowed to settle undisturbed. In general, clay was introduced at the beginning of an experiment, although in experiment 2 a given amount of clay was added to each set at hourly intervals for 10 hours. Two types of clay, montmorillonite and kaolinite, were used, the former only in experiment 1 and the latter in experiments 2 through 6. Montmorillonite and kaolinite are common clay minerals in muds of bays and estuaries and provide some basis for comparison with mud in a natural situation.

The sets of clams were buried under different amounts of clay for different periods of time. This was done to obtain some estimate as to the cumulative effect on mollusks of increased loads of clay with an increased period of burial. Amount of clay was generally separated into three categories so that the three sets of bivalves were buried under three different loads or groups of clay. The loads ranged from 10 to 20 g in experiment 1, 10 to 20 to 30 g in experiment 2, and 10 to 30 to 50 g in experi-

ments 4 through 6. Experiment 3 contained a control or no kaolinite group with 2 groups of 50 and 100 g. Elapsed burial time ranged from 5 hours to 31.5 hours with the majority of experiments varying from 24 to 30 hours.

At the end of the burial periods sets of clams were unearthed from the clay and placed on top of clean sand in beakers of sea water. A continuous flow of water was supplied. Survivorship was recorded as well as burrowing and siphonal activity to assess the general condition of the pelecypods. Dead clams were easy to distinguish from live ones as the former were always agape. Following the disinterment similar observations were noted at various intervals. Finally the experiment was terminated and dissections were performed on the test mollusks.

## RESULTS

The number of clams buried, the number dead and alive when they were unearthed, and the number dead and alive after a period in clean sea water, are listed in Table 1. The relative amount of clay found in the mantle cavity and the occurrence of feces and pseudofeces associated with each species are summarized in Table 2.

**Experiment 1:** After 5 hours of burial the specimens were all alive when they were unearthed. *Transennella tantilla* in the 10 and 20 g groups responded immediately to clean sea water by burrowing and extending their siphons. Almost 12 hours after *Tellina salmonea* from the 20 g group had been uncovered, two individuals were still on the surface of the sand and one specimen had died. During this period the majority of these mollusks burrowed into the sand and were actively waving their siphons in the water. *Tellina buttoni* showed a gradual response to being uncovered and placed in clean sea water, as 15 hours after they were unearthed all the bivalves in the 10 g group and 9 members of the 20 g group had burrowed. Information from dissections indicated that *Tellina buttoni* contained more clay than either *T. salmonea* or *Transennella tantilla*, both of which were relatively clean. Although *Tellina salmonea* sustained one mortality, this tellinid and *Transennella tantilla* were less adversely affected by the experiment than *Tellina buttoni*.

**Experiment 2:** Elapsed burial time was 24 hours and this was the only experiment in which clay was added at hourly intervals for many hours. When *Transennella tantilla* was removed from the clay, it responded immediately to clean sea water by burrowing and extending its siphons. Within 10 to 15 minutes after being uncovered *Tellina buttoni* began to revive and *T. salmonea* began to respond after 30 minutes. Five hours after *Tellina salmonea* had been removed from the clay all test animals had revived

except two individuals from the 20 g group. The two mortalities and the relatively slow rate of recovery indicated that *Tellina salmonea* had the most difficult time withstanding the hourly loads of clay. *Transennella tantilla* and *Tellina buttoni* survived the experiment about equally well.

**Experiment 3:** Elapsed burial time was about 31.5 hours and when the specimens were uncovered, they were all alive. Sixteen hours later one each of *Tellina buttoni* and *Transennella tantilla* from the control beakers were dead, 5 *Tellina buttoni* and 2 *Transennella tantilla* were dead

in the 50 g group, and 3 *Tellina buttoni* and 2 venerids were dead in the 100 g group. *Tellina salmonea* and *Transennella tantilla* appear to have been less affected by the clay and responded more rapidly to the sea water than *Tellina buttoni*. Although 5 *Transennella tantilla* died during the experiment its recovery rate and lack of clay ingestion indicated that the small venerid was second in survivorship for this experiment.

**Experiment 4:** Elapsed burial time was 28.5 hours and after this period 5 *Tellina buttoni* in the 30 and 50 g groups were dead. About 2 hours after the mollusks had

Table 1

Summary of Burial Experiments 1 through 6.

Results expressed as number of live (L) and dead (D) clams after burial period and during periods of revival.

		Tb	Ts	Tt	Tb	Ts	Tt	Tb	Ts	Tt
Cumulative Elapsed Time hr:min										
1. Montmorillonite		10 grams			20 grams			30 grams		
Buried	00:00	10L	10L	10L	8L	10L	10L			
Unearthed	05:00	-	-	-	-	-	-			
Revival	16:45	-	-	-	-	9L-1D	-			
Revival	89:00	10L	10L	10L	8L	9L-1D	10L			
2. Kaolinite		One, two, and three grams at hourly intervals for ten hours								
Buried	00:00	4L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	24:00	-	-	-	-	-	-	-	-	-
Revival	29:00	4L	10L	10L	5D	8L-2D	10L	5L	10L	10L
3. Kaolinite		Control (no Kaolinite)			50 grams			100 grams		
Buried	00:00	5L	10L	10L	5L	10L	10L	3L	8L	10L
Unearthed	31:25	-	-	-	-	-	-	-	-	-
Revival	47:10	4L-1D	10L	9L-1D	5D	10L	8L-2D	3D	8L	8L-2D
4. Kaolinite		10 grams			30 grams			50 grams		
Buried	00:00	5L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	28:30	-	-	-	5D	-	-	5D	-	-
Revival	30:15	4L-1D	-	-	-	-	-	-	-	-
Revival	41:00	3L-2D	10L	10L	5D	10L	10L	5D	4L-6D	10L
5.										
Buried	00:00	5L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	29:15	-	-	-	-	-	-	-	-	-
Revival	41:15	4L-1D	10L	10L	5D	10L	10L	5D	10L	9L-1D
6.										
Buried	00:00	5L	10L	10L	5L	10L	10L	5L	10L	10L
Unearthed	24:00	-	-	-	-	-	-	-	-	-
Revival	30:00	5L	8L-2D	10L	4L-1D	7L-3D	9L-1D	2L-3D	8L-2D	10L

Tb = *Tellina buttoni*, Ts = *Tellina salmonea*, Tt = *Transennella tantilla*

been unearthed, 1 *T. buttoni* from the 10 g group had died. During the final 10 hours of the experiment another *T. buttoni* in the 10 g group and 6 *T. salmonea* in the 50 g group died. *Transennella tantilla* survived the experiment in good condition and upon dissection was found to contain less clay material than *Tellina salmonea* or *Tellina buttoni*. The former tellinid finished the experiment in better condition than the latter.

**Experiment 5:** Elapsed burial time was approximately 29 hours, and all the sets were alive when they were uncovered. Twelve hours later 1, 5, and 5 specimens of *Tellina buttoni* had died in the three clay groups respectively, while 1 *Transennella tantilla* in the 50 g group died. *Tellina salmonea* survived the experiment slightly better than *Tr. tantilla* and both species fared considerably better than *Tellina buttoni*.

**Experiment 6:** In the last experiment elapsed burial time was 24 hours and all the sets survived the burial period. Six hours after *Tellina salmonea* had been uncovered, 2, 3, and 2 specimens respectively had died. Three *Tellina buttoni* in the 50 g group and 1 each of *T. buttoni* and *Transennella tantilla* in the 30 g group had died during the same period.

## DISCUSSION

MAURER (1967) cautioned against placing undue reliance on the comparative results of filtering experiments, unless similar ctenidial and feeding types were compared. The same warning applies to the present research.

The ctenidial structure of the tellinids and of *Transennella tantilla* are different and the pelecypods are reputed to feed differently. For example, the size of the ctenidia in the tellinids is reduced in comparison with the size of the labial palps, whereas in *Transennella tantilla* the palps are relatively minor features compared with its ctenidia. *Transennella tantilla* is probably a suspension feeder and the tellinids have been considered deposit feeders (YONGE, 1949). Nevertheless, more and more evidence is accumulating on the mode of feeding of *Tellina salmonea* and *T. buttoni* that these tellinids may not be restricted to one mode of feeding. Thus it is not surprising, given different modifications in ctenidial structures and more complex feeding behavior, that their response to the effect of heavy loads of clay should be very different.

Among the three species, *Transennella tantilla* most successfully survived the burial experiments as only 7 individuals out of 170 specimens died (Table 1). Six of the mortalities occurred under the influence of the heavier clay loads. When *Tr. tantilla* was placed in clean sea water, its response (burrowing, siphonal activity, excretory func-

tion) was almost immediate, and in general, individuals rarely contained much clay. The venerid also produced more feces and pseudofeces than the 2 tellinids (Table 2). This indicated that it was able to ingest the clay, process it through the alimentary tract, and form some fecal pellets. Correspondingly with increased loads of clay it was able to withstand the added sedimentation by rejecting material in the form of pseudofeces.

It appears that marked survivorship of *Transennella tantilla* under muddy conditions of burial, and its renewed activity in clean sand and fresh sea water, are in accord with the high filtering rate and ease of digestion recorded earlier from filtering experiments (MAURER, 1967). These data support the view that *Tr. tantilla* can tolerate a variety of sediment types and the turbid conditions raised particularly during deposition of fine sand and mud. Based on tolerance to turbidity it would be expected to find *Tr. tantilla* living in sediment that ranges in particle size from mud to coarse sand.

Interpretation of experimental evidence for the tellinids is not as clear cut. For example, *Tellina salmonea* was relatively successful in surviving the loads of clay as 16 individuals out of 168 specimens died and 14 of these occurred in heavier loads. Although its rate of filtering was relatively low in the filtering experiments, it inhaled and processed suspensions with far greater facility than *T. buttoni* (MAURER, 1967). From its optimal development in clean, medium to coarse sand (MAURER, 1966), it would be expected that burial in clay would be extremely harmful to *T. salmonea*. In the burial experiments its response to clean sand and fresh sea water was the slowest among the species, yet its number of mortalities was considerably less than that of *T. buttoni* and only twice that of *Transennella tantilla*. In addition, results of dissection showed that *Tellina salmonea* was rarely full of clay and that it did produce some feces and pseudofeces. This indicates its ability to inhale and digest fine material in turbid water at least for the limited periods defined by the experimental design. *Tellina salmonea* has been collected from turbid conditions by REISH (1961), but it is a site where this tellinid is not best represented. Again information on mode of feeding might explain the apparent inconsistency between its preferred distribution in coarse sand and its ability to withstand turbid conditions not usually a part of that sedimentary regime.

*Tellina buttoni* survived the experiment in very poor condition as 36 out of 90 individuals died and 32 of these deaths were again in the heavier loads. Even though *T. buttoni* had a relatively high clearing rate, it had difficulty inhaling and digesting the suspensions used in the filtering experiments (MAURER, 1967). From its optimal development in fine sand with some organic material (MAURER,

Table 2  
Relative Amount of Clay found in Clams and the Occurrence of Feces  
and Pseudofeces for Experiments 1 through 6

1. Montmorillonite	10 grams	20 grams	30 grams
<i>Tellina buttoni</i>	**	** F	
<i>Tellina salmonea</i>	* F	*	
<i>Transennella tantilla</i>	-	-	
2. Kaolinite	One, two and three grams at hourly intervals for 10 hours.		
<i>Tellina buttoni</i>		Unexamined	
<i>Tellina salmonea</i>		Unexamined	
<i>Transennella tantilla</i>	P	P	P
3. Kaolinite	Control (no Kaolinite)	50 grams	100 grams
<i>Tellina buttoni</i>	-	*** P	*** P
<i>Tellina salmonea</i>	-	* P	** P
<i>Transennella tantilla</i>	- P	** P	Unexamined
4. Kaolinite	10 grams	30 grams	50 grams
<i>Tellina buttoni</i>	*	**	***
<i>Tellina salmonea</i>	*	**	***
<i>Transennella tantilla</i>	-	* P&F	* P&F
5.			
<i>Tellina buttoni</i>	-	****	****
<i>Tellina salmonea</i>	* F	**	*
<i>Transennella tantilla</i>	-	-	*
6.			
<i>Tellina buttoni</i>	* F	* F	***
<i>Tellina salmonea</i>	- F	*	**
<i>Transennella tantilla</i>	- F	**	**

- = clean; \* = trace; \*\* = small; \*\*\* = moderate;  
\*\*\*\* = heavy; F = feces; P = pseudofeces

1966), it would seem that burial in clay would be less harmful to *T. buttoni* than to *T. salmonea*. Still, in the burial experiments it experienced greatest mortalities, commonly became filled with clay, and produced the least amount of feces and pseudofeces. The amount of clay found in these clams during dissections indicated that they were unable to pass the clay easily through their digestive system, and as a result, they eventually became packed and died. Combination of heavy loads of clay with a specific mode of feeding might explain its inability to cope with the unnatural conditions of sedimentation encountered in the laboratory. Thus, experimental evidence does not, at present, indicate the reason or reasons for the observed preference of *Tellina buttoni* for fine sand.

In conclusion, burial experiments have shown that the number of mortalities and the production of feces and pseudofeces increased as the burial load was increased for all species. *Transennella tantilla* had the smallest number of mortalities and was best able to cope with the turbid conditions of the experiments. Survivorship rate and condition of *Tellina salmonea* and *Tellina buttoni* followed in that order. Results of filtering and burial experiments supply added evidence to further elucidate the occurrence of *Transennella tantilla* in a variety of sediment types. On the other hand, aside from the sediment as a source of food and a possible turbidity regime, experimental data do not presently provide an explanation for the more restricted sediment preference of the tellinids.

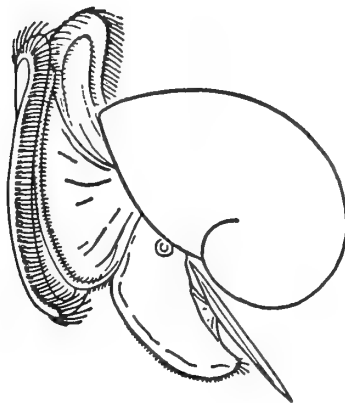


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A Review of *Amoria damonii* GRAY, 1864  
and Two New Species Names Proposed for the Homonyms  
*Voluta bullata* SWAINSON, 1829 and *Voluta lineata* LEACH, 1814

(Gastropoda : Volutidae)

BY

CLIFTON STOKES WEAVER<sup>1</sup>

AND

JOHN ELEUTHÈRE DUPONT<sup>2</sup>

(Plates 52, 53; 1 Map)

DURING THE PAST 125 years various authors have given different scientific names to shells representing widely separated populations of the endemic Australian gastropod mollusk *Amoria damonii* GRAY, 1864, when these populations differed in appearance from GRAY's original figure. We are illustrating GRAY's holotype in Plate 52, Figure 3.

Recently large numbers of *Amoria damonii* have been collected at dozens of localities connecting the once isolated areas. A study of this new evidence shows that the earlier taxa simply represented population variants living along a continuous coastal cline beginning at Thevenard Island, central Western Australia, and extending in a clockwise direction to Cooktown, Queensland. Each population grades into and is replaced by succeeding populations without interruption.

A darkly reticulated color form, similar to the *Amoria damonii* population at Dolphin Island, Dampier Archipelago (Plate 52, Figure 2), was named *Voluta reticulata* REEVE, 1844 (*non* LINNAEUS, 1767 = *Cancellaria reticulata*).

Along the northern Australian coastline, specimens show a gradual color gradation from typical *Amoria damonii* at Broome (Plate 52, Figure 4) to an almost patternless shell found off Port Keats (Plate 52, Figure 6). This lightly patterned color form was given the name *Voluta (Amoria) gatliffi* by G. B. SOWERBY III in 1910. The

name *gatliffi* was preoccupied: it was given by PRITCHARD (1898) to a fossil species of volute in the genus *Livonia* GRAY, 1855; the name, therefore, is a homonym. In any case, SOWERBY's species is synonymous with *A. damonii*. LUDBROOK (1953) described a population with similar markings from off Port Keats, Northern Territory, giving it the name *Amoria (Amoria) keatsiana*. For her holotype LUDBROOK used the same specimen that SOWERBY had used as the holotype for *gatliffi* (Plate 52, Figure 6). However, she provided for future revision by stating: "Two possibilities are presented:

(1) That the species *damoni* is variable in its color pattern in a series of which typical *damoni* and typical *keatsiana* are end members, *keatsiana* thus becoming a synonym;

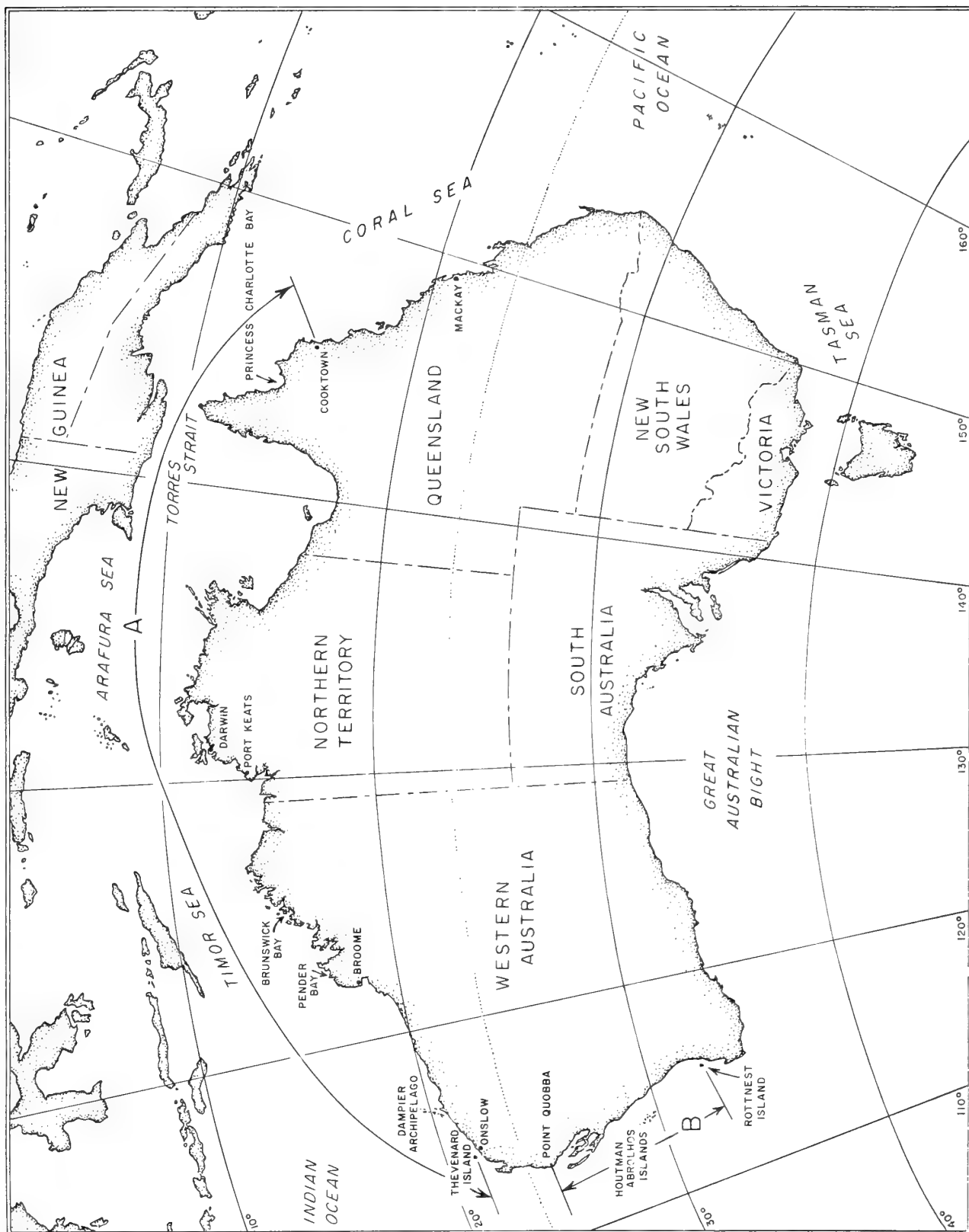
(2) That a cline exists between the two species *damoni* and *keatsiana*. Only a study of considerably more material and more accurate determination of the geographical range of each species will determine which is preferable."

With much more material now at hand than was at LUDBROOK's disposal, we can readily see that a cline does exist and that it does not stop at Port Keats, but continues on to Cooktown, North Queensland. Thus LUDBROOK's *Amoria keatsiana* becomes a synonym of *A. damonii*.

There is a terminal population at the south-western end of the range of *Amoria damonii*, which is isolated from it by a geographical gap. This population was given the name *Voluta reevei* by G. B. SOWERBY II in 1864. We are illustrating the holotype of SOWERBY's species in Figures

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<sup>2</sup> Delaware Museum of Natural History, Greenville, Delaware



9 and 10, Plate 53. Unless future collecting brings to light intergrading specimens which close this gap, this population can be considered a subspecies of *A. damonii*.

The north-eastern terminal population at Cooktown, Queensland (Plate 52, Figure 8) is not geographically isolated and, as an integral part of the coastal cline, does not deserve subspecific recognition.

Following is a brief outline of the genus and an analysis of the species in question.

#### Scaphellinae H. & A. ADAMS, 1858

1858. Scaphellinae H. & A. ADAMS, The genera of recent mollusca; London, 2: 619

#### *Amoria* GRAY, 1855

1855. *Amoria* GRAY, Proc. Zool. Soc. London 23: 64

**Type species:** *Voluta turneri* GRAY in GRIFFITH & PIDGEON, 1834; Recent, Australia; by SD of HARRIS, 1897.

#### (*Amoria*, s. str.)

1855. *Amoria* GRAY, Proc. Zool. Soc. London 23: 64

*Amoria (Amoria) damonii damonii* GRAY, 1864  
(Plate 52; Figures 1 to 8)

1844. *Voluta reticulata* REEVE, Proc. Zool. Soc. London 11: 144 [non LINNAEUS, 1767; non GMELIN, 1791; non REEVE, 1845; non SOWERBY I, 1845]

1845. *Voluta pallida* GRAY. SOWERBY I, Thes. Conch. 1 (5): 196 (pars); plt. 53, fig. 94 [non *pallida* LINNAEUS, 1767]

1855. *Amoria reticulata* GRAY, Proc. Zool. Soc. London 23: 64

1864. *Amoria turneri damonii* GRAY, Ann. Mag. Nat. Hist. 14 (3): 237 (no locality given)

1910. *Voluta (Amoria) gatliffi* SOWERBY III, Ann. Mag. Nat. Hist. 6 (ser. 8): 611; text fig. [non PRITCHARD, 1898]

1914. *Scaphella hedleyi* IREDALE, Proc. Zool. Soc. London, p. 674 [nom. mut. for *Voluta reticulata* REEVE, 1844 (non LINNAEUS, 1767)]

1953. *Amoria (Amoria) keatsiana* LUDBROOK, Proc. Malacol. Soc. London 30: 138; plt. 18, fig. 9

1964. *Amoria damoni damoni* GRAY. WEAVER, Hawaiian Shell News 12 (6): 7; fig. 3

1964. *Amoria damoni damoni* GRAY. WEAVER, Hawaiian Shell News 12 (11): 5; figs. 1 - 5

**Holotype:** British Museum (Natural History) Number 1862.6.4.1 [LUDBROOK's, 1953, BM(NH) catalogue number is here corrected (Tebble, *in litt.*)].

**Type Locality:** Designated by LUDBROOK (1953): North of Swan River, Western Australia.

**Range:** From Thevenard Island, central Western Australia, in a north-easterly direction to Princess Charlotte Bay, north Queensland, a distance of about 3000 miles (see Map). Vertical distribution extends from the littoral to several fathoms.

**Shell Description:** Coloring and shape of shell vary considerably in individual populations along the 3000 mile coastal range of *Amoria damonii damonii* (Plate 52, Figures 1 - 8); shell large, length at least 123 mm, elongate-ovate with elevated nipple-like spire. Sutures slightly impressed, otherwise shell's exterior smooth. Columella with 4 sharp, oblique plaits.

Color of shells from Broome area: Nucleus white for first 1½ whorls, then fawn with white subsutural line continuing to first postnuclear whorl. Penultimate whorl

## Explanation of Plate 52

Dorsal and Ventral Aspects Showing Variation of Color Pattern  
in *Amoria damonii damonii* GRAY, 1864, throughout its Range of Distribution.

Figure 1: *Amoria d. damonii* from Thevenard Island, central Western Australia; found buried under sand on exposed sand bar at low tide by C. Weaver.

Figure 2: *Amoria d. damonii* from Dolphin Island, Dampier Archipelago, central Western Australia; found buried under sand on exposed sand bar at low tide by C. Weaver.

Figure 3: Holotype of *Amoria turneri damonii* GRAY, 1864 (= *Amoria damonii damonii*), British Museum (Natural History); no locality given.

Figure 4: *Amoria d. damonii* s. str., from Broome, north Western Australia; collected by A. R. Whitworth.

Figure 5: *Amoria d. damonii* from Brunswick Bay, north Western Australia.

Figure 6: Holotype of *Amoria (Amoria) keatsiana* LUDBROOK, 1953 (= *Amoria damonii damonii*), British Museum (Natural History); taken near Port Keats, Northern Territory.

Figure 7: *Amoria d. damonii* taken by divers in 15 fathoms from Princess Charlotte Bay, North Queensland.

Figure 8: *Amoria d. damonii* taken by Carl Kurtze in 8 fathoms off Dawson Reef, just south-east of Cooktown, north Queensland.

{Figures 3, 6 and 7: © British Museum (Natural History); all others taken by C. Weaver.}



Figure 1



Figure 2



Figure 3

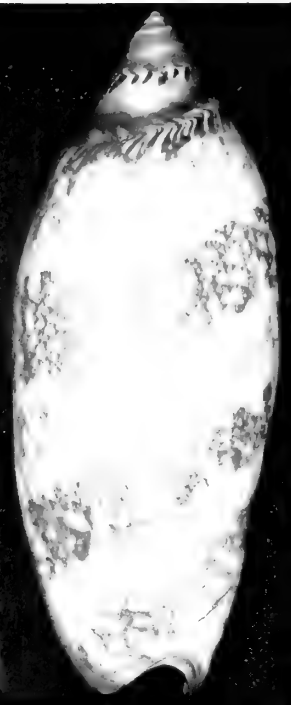


Figure 4



Figure 5



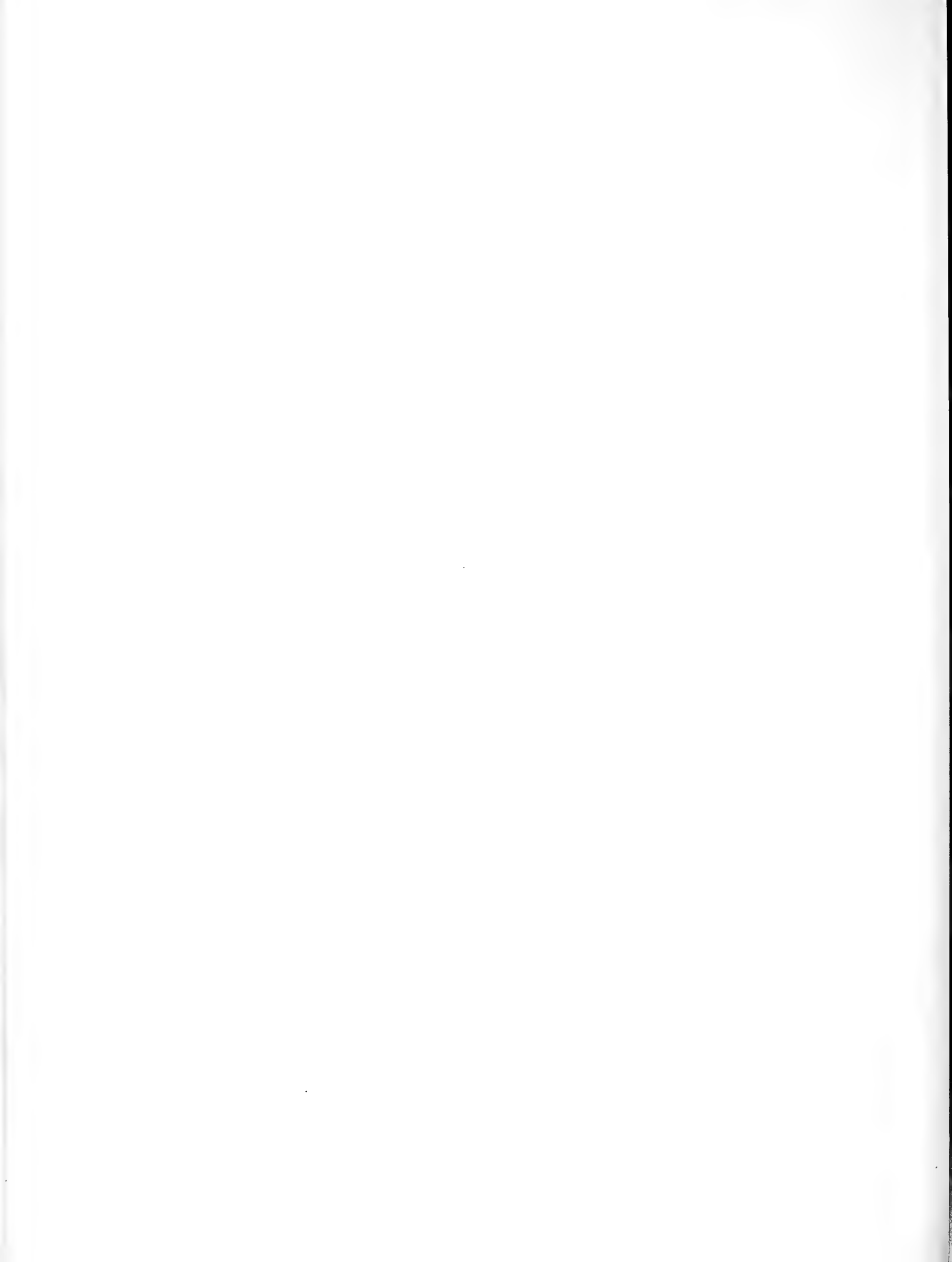
Figure 6



Figure 7



Figure 8



a rich shining chestnut, body whorl cream with 2 or 3 broad revolving bands of fine triangular brown reticulations. Post-nuclear sutures obliquely streaked with darker brown. Aperture a rich coffee color inside, columella white, fasciole bordered with brown.

*Amoria (Amoria) damonii reevei* (SOWERBY II, 1864)

(Plate 53; Figures 9 - 13)

1845. *Voluta reticulata* REEVE, SOWERBY I, Thes. Conch. 1 (5): 197; plt. 49, figs. 47, 48 [non LINNAEUS, 1767, non GMELIN, 1791; non REEVE, 1844]  
 1864. *Voluta reevei* SOWERBY II, Thes. Conch. 3 (23): 269, 1<sup>st</sup> supp. (Australia)  
 1964. *Amoria damoni reevei* SOWERBY II. WEAVER, Hawaiian Shell News 12 (6): 7; fig. 1  
 1964. *Amoria damoni damoni* GRAY. WEAVER, Hawaiian Shell News 12 (6): 7; fig. 2

**Holotype:** British Museum (Natural History) No. 1843.3. 31.6. [LUDBROOK's (1953) BM(NH) catalogue number is here corrected (Tebble, *in litt.*)]

**Type Locality:** Here designated Rottnest Island, south Western Australia, Long. 115° 30' E; Lat. 32° 00' S, where a number of crab occupied specimens have been taken from craypots (Plate 53, Figures 11, 12) in 20 to 30 fathoms.

**Range:** From Fremantle north to Point Quobba, a distance of about 550 miles (see Map). Apparently a deep water form.

**Shell Description:** Shell rather large, with swollen body whorl and low spire producing an inflated appearance. Color pinkish-cream with golden brown reticulations concentrated in two broad spiral bands. In all other respects similar to the nominate subspecies.

**Remarks:** Although specimens of this rare subspecies from off Point Quobba (Plate 53, Figure 13) tend to approach the form of typical *Amoria damonii damonii* by virtue of their higher spire, no intergrades have been found connecting *A. d. reevei* with the more northerly nominate subspecies. Since there appears to be a geographical gap separating the two subspecies, they are considered separately here.

#### NEW NAMES PROPOSED FOR TWO HOMONYMS

Several years ago, Mr. Walter Cernohorsky brought to our attention the fact that two long-established names in

Volutidae were homonyms. These names are *Voluta bullata* SWAINSON, 1829, and *Voluta lineata* LEACH, 1814.

*Voluta bullata* SWAINSON (see Plate 53, Figure 14: holotype) is an east South African volute which GRAY (1847) designated as type species for his monotypic genus *Callipara*. It is regrettable that he did not realize that the name *bullata* was preoccupied in *Voluta* at least 3 times by earlier authors:

1778. *Voluta bullata* BORN, Index Mus. Caes. Vindob., p. 205 [belongs in Marginellidae]  
 1791. *Voluta bullata* GMELIN, Syst. Nat., ed. 13, p. 3452, no. 129 [GMELIN cites CHEMNITZ, vol. 10, p. 159; plt. 150, figs. 1409 and 1410, which is *Marginella bullata* (BORN, 1778). He also cites MARTINI, LISTER, KNORR, BUONANNI and BORN, all referring to *Marginella bullata* (BORN, 1778)]  
 1828. *Voluta bullata* WOOD, Index Test., 2nd. ed.; plt. 20, fig. 70 [= *Marginella bullata* (BORN, 1778)]

In proposing the following new name for SWAINSON's *Callipara bullata*, we have altered it only enough to make it taxonomically acceptable.

*Callipara bullatiana* WEAVER & DUPONT, nom. nov.

(Plate 53, Figure 14)

**Synonymy:** *Voluta bullata* SWAINSON, 1829, Zool. Illustr., vol. 1, ser. 2; plt. 15 (*Voluta* plt. 1) [non BORN, 1778; non GMELIN, 1791; non WOOD, 1828]

**Holotype:** British Museum (Natural History) No. 1966617 (Plate 53, Figure 14)

**Type Locality:** Designated by SOWERBY II (1845): Algoa Bay, South Africa.

The second homonym requiring a new name is *Voluta lineata* LEACH, 1814, an eastern Australian volute belonging in the genus *Zebramoria* IREDALE, 1929. The holotype of *Z. lineata* is shown in Figures 15 and 16, Plate 53. The earlier reference invalidating this name is:

1791. *Voluta lineata* GMELIN, Syst. Nat., ed. 13; p. 3454, no. 66 [GMELIN cites MARTINI, vol. 4; plt. 149, figs. 1378 and 1379, which are figures of a *Mitra*]

In proposing a new name for *Zebramoria lineata* (LEACH, 1814), we have followed the same course as with

the preceding species, *i. e.* altering the name only enough to make it taxonomically acceptable.

**Type Locality:** Designated by LUDBROOK (1953): Queensland, Australia.

*Zebramoria lineatiana* WEAVER & DUPONT, nom. nov.

(Plate 53; Figures 15 and 16)

**Synonymy:** *Voluta lineata* LEACH, 1814, Zool. Miscell., vol. 1; p. 31; plt. 12, fig. 2 [*non* GMELIN, 1791]

**Neotype:** British Museum (Natural History) No. 1952.3.21.2 (Plate 53, Figures 15 and 16)

## ACKNOWLEDGMENTS

We are deeply indebted to Mr. Norman Tebble, Department of Zoology, British Museum (Natural History), London, England for his help in securing the fine photographs of type material that appear in this paper. We also wish to thank Mrs. Jean Cate for the time and effort so generously given in editing our manuscript and Mr.

Table 1

*Amoria damonii damonii* GRAY, 1864; *Amoria damonii reevei* (SOWERBY II, 1864);  
*Callipara bullatiana* WEAVER & DUPONT, nom. nov.;  
*Zebramoria lineatiana* WEAVER & DUPONT, nom. nov.

Specimen	Maximum		Collection and Museum Number
	Length	Diameter	
Plate 52			
Figure 1	79.70	36.35	Delaware Museum, No. 10052
Figure 2	94.00	37.95	Delaware Museum, No. 10051
Figure 3	78.30	33.20	Holotype, BM(NH) No. 1862.6.4.1
Figure 4	98.60	41.90	Delaware Museum, No. 10071
Figure 5	98.85	40.51	Delaware Museum, No. 10055
Figure 6	95.00	36.30	Holotype, BM(NH) No. 1911.6.21.1
Figure 7	86.10	32.65	Delaware Museum, No. 10057
Figure 8	87.70	32.45	Delaware Museum, No. 10058
Plate 53			
Figure 9, 10	99.00	53.20	Holotype, BM(NH) No. 1843.3.31.6
Figure 11, 12	102.65	52.45	Delaware Museum, No. 10073
Figure 13	108.65	46.60	E. M. Buchanan
Figure 14	63.90	30.40	Holotype, BM(NH) No. 1966617
Figure 15, 16	51.60	26.30	Neotype, BM(NH) No. 1952.3.21.2

(Measurements in millimeters; BM(NH) = British Museum (Natural History))

## Explanation of Plate 53

Dorsal and Ventral Aspects of *Amoria damonii reevei* (SOWERBY II, 1864), *Callipara bullatiana* WEAVER & DUPONT, nom. nov. and *Zebramoria lineatiana* WEAVER & DUPONT, nom. nov.

Figures 9 and 10: Holotype of *Voluta reevei* SOWERBY II, 1864 (= *Amoria damonii reevei*), British Museum (Natural History).

Figures 11 and 12: *Amoria damonii reevei*, crab-occupied shell taken from crayfish pot in 25 fathoms, off Rottnest Island, south Western Australia.

Figure 13: *Amoria damonii reevei*, crab-occupied shell trawled by fisherman from 20 fathoms off Point Quobba, central Western Australia; ex E. M. Buchanan coll.

Figure 14: Holotype of *Voluta bullata* SWAINSON, 1829 (= Holotype of *Callipara bullatiana* WEAVER & DUPONT, nom. nov.); British Museum (Natural History).

Figures 15 and 16: Neotype of *Voluta lineata* LEACH, 1814 (= Holotype of *Zebramoria lineatiana* WEAVER & DUPONT, nom. nov.); British Museum (Natural History).

{Figures 9, 10, 14, 15 and 16 © British Museum (Natural History); all others taken by C. Weaver.}



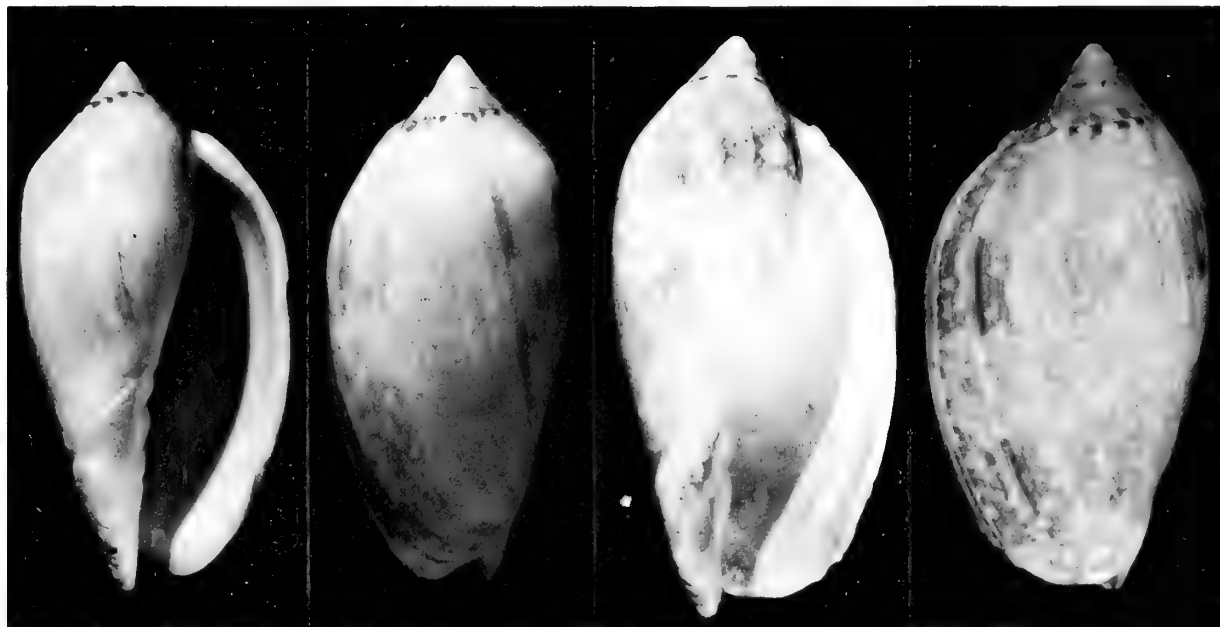


Figure 9

Figure 10

Figure 11

Figure 12

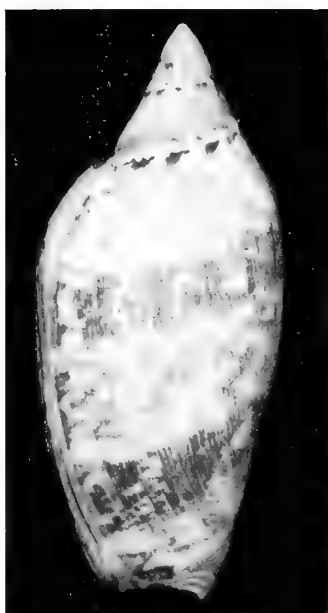


Figure 13



Figure 14

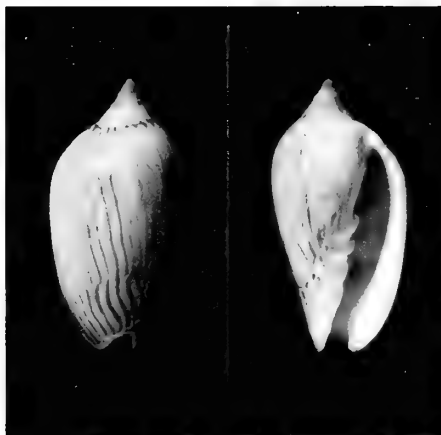


Figure 15

Figure 16



A. R. Whitworth who supplied several rare *Amoria damonii* forms from remote areas.

### LITERATURE CITED

Note: Parts of the Thesaurus Conchyliorum, 1842 - 1887 ( 5 vols., 44 prts.) were authored by all three of the G. B. SOWERBYS. The authors and publication dates of these various parts were recorded by WOODWARD in the library catalogue (vol. 5, p. 1981) of the Zoological Library, British Museum (Natural History), London, according to the dates of their receipt.

A photostatic copy of page 1981 was kindly sent to us by Mr. Gavin Bridson, Departmental Librarian, BM(NH). From these entries we have credited the proper SOWERBY for the parts he authored and have shown the accepted publication dates as they pertain to the Volute species in question.

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#### PRITCHARD, GEORGE B.

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#### SOWERBY, GEORGE BRETtingham (second of name)

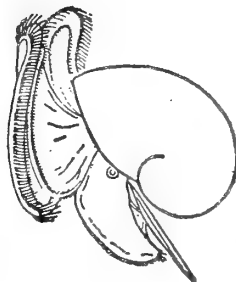
1864. Completion of the late G. B. Sowerby's monograph of *Voluta*. *Thes. Conch.* 3 (23), 1<sup>st</sup> suppl.: 269 (1864) [According to WOODWARD there is no month-date for this reference. Therefore, it must date from December 31, 1864]

#### SOWERBY, GEORGE BRETtingham (3rd of name)

1910. Description of a new Volute. *Ann. Mag. Nat. Hist. ser. 8*, 6: 611; text fig. (December 1910)

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## Age and Environment of a Marine Terrace Fauna, San Clemente Island, California

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(4 Text figures)

### INTRODUCTION

SAN CLEMENTE ISLAND, the southernmost of the California Channel Islands (Figure 1a), is well known for its striking step-like series of marine terraces extending from near sea level to the top of the island. As early as 1893, LAWSON (1893: p. 131) measured with an aneroid barometer the elevation of 19 terraces ranging from 12 to 1500 feet above sea level. Later, SMITH (1898: p. 475) recorded 23 terraces between 12 and 1365 feet. EMERY (1960: pp. 7, 35), using published topographic maps, estimated the elevations of 16 terraces from about 50 to 1925 feet above sea level and listed about 7 submarine terraces down to nearly 600 feet below sea level.

Many of these terraces are devoid of marine deposits and thus fossils are rarely found. SMITH (1898: p. 476) reported a single species, the pelecypod *Lucina californica* CONRAD, from an unspecified locality, and later COCKRELL (1939) listed 33 molluscan species from a terrace deposit at about 800 feet in elevation. Fossils have not been previously recorded from lower terraces. The present paper records a marine fauna, predominantly foraminifera, ostracods and mollusks, collected from a terrace about 80 feet above sea level at Horse Cove near the southern end of the island.

### GEOLOGIC SETTING

San Clemente Island is composed largely of Miocene volcanic rocks with some interbedded marine sediments

(OLMSTED, 1958: pl. 1). At Horse Cove the area is underlain by Miocene diatomite and pumice breccia which overlie and are faulted against andesite. On this part of the island marine terraces are numerous and their form well preserved, but sediment and fossils are not commonly exposed on them due to burial by alluvium, or are not present because they have apparently been removed by erosion. However, on one terrace surface marine fossiliferous sediment is exposed at an elevation of about 80 feet (Figure 1b). This exposure was traced laterally several hundred feet, but shells from overlying Indian kitchen middens contaminate the fossiliferous outcrops except at one locality (UCLA 4936). The shoreline angle of the terrace lies about 200 feet north of this locality at an elevation of about 100 feet (Figure 1b).

At the fossil locality, the marine terrace deposits, which consist of boulder- to sand-sized clasts, lie on Miocene diatomite. These terrace sediments are extremely well cemented so that removal of fossils is very difficult. The deposit is overlain by 2 - 3 feet of alluvium, which consists of soil and volcanic clasts up to several feet across (Figure 2).

### PALEONTOLOGY

The fauna collected from the Horse Cove locality includes 18 species of foraminifera, 16 gastropods, 4 pelecypods, 2 echinoids, 8 ostracods, a cetacean, and several unidentified species of bryozoa.

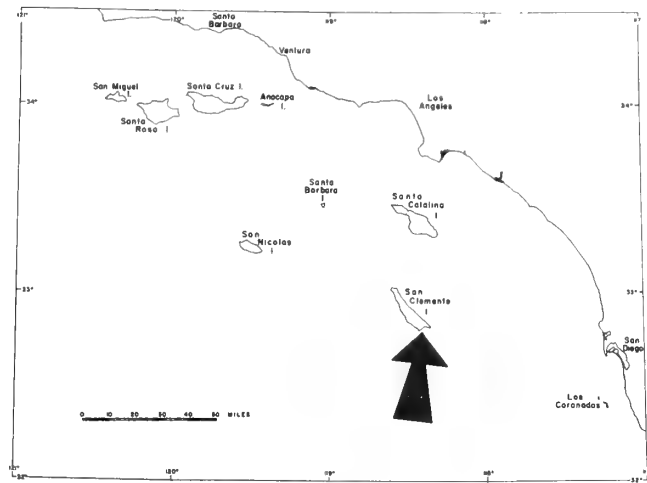
#### Figure 1

A. Southern California Channel Islands.

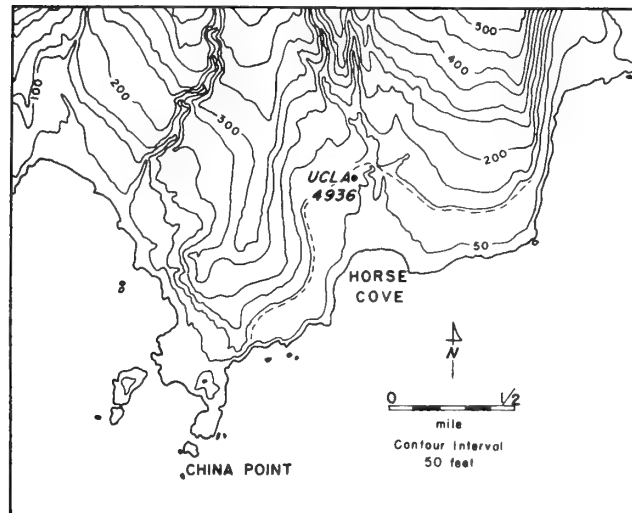
(The arrow indicates the Horse Cove area at the southern end of San Clemente Island.)

B. Horse Cove area, San Clemente Island showing the collecting locality (UCLA 4936) in Pleistocene marine terrace sediments.

The approximate position of the former shoreline associated with the deposits is indicated by the dashed line.



A



B

## FORAMINIFERIDA

Foraminiferal faunas from marine terrace sediments in California have not been studied previously in detail, yet foraminifera commonly occur in these sediments. A few species of foraminifera have been recorded incidental to studies of other terrace problems, but no fauna has been

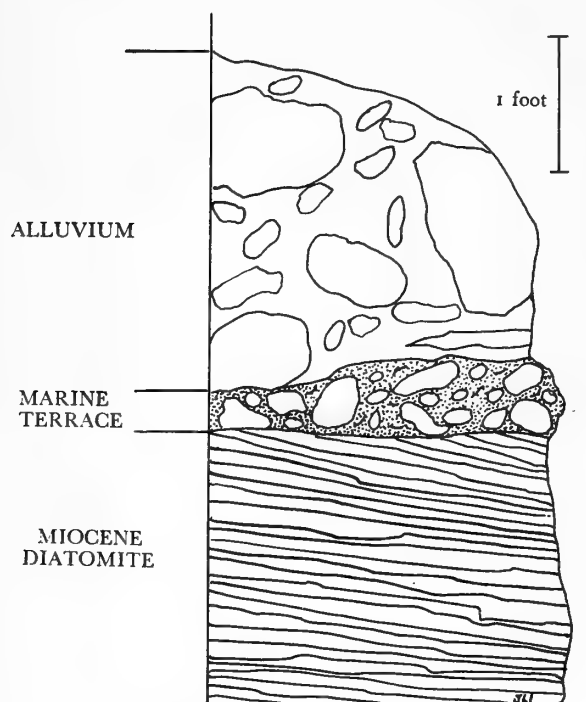


Figure 2

Columnar Section of Rock Units exposed at UCLA 4936.

adequately described. Foraminifera probably have been ignored in terrace deposits because they mostly occur in coarse-grained sediments. This necessitates much searching without encouraging results and the specimens so obtained are generally worn and leached. Furthermore, reworking of geologically older forms into the deposits is common. Mollusks are more apparent and therefore have been utilized previously in solving terrace problems. However, having proved useful in age dating and correlation of older rocks, and for determining past and present environmental factors, foraminifera should provide a rich source of data which will assist in interpreting the significance of terraces and their deposits. Therefore, I have documented this foraminiferal fauna as completely as possible.

In order to find foraminifera, terrace sediment, excluding the larger clasts, was soaked in kerosene, and then boiled in water, washed over a 200 mesh Tyler screen (openings  $74\mu$ ) and dried. The dry sediment, mostly sand, was shaken into a heavy liquid to separate the foraminifera from the sand by flotation. The light residue consisted mostly of fossils or their fragments, and the heavy fraction was mostly sand. The sand was searched to determine if all foraminifera had floated, but many additional ones were found in it.

An attempt to compile data on the geographic distribution of the species found at Horse Cove was undertaken from the literature. These ranges could not be accepted as completely valid because of some published misidentifications of species. A critical study of ranges would require re-examination of the specimens on which the identifications were based and a study of collections from many places at different depths along the coast of the Americas.

The foraminiferal fauna collected at Horse Cove is a small one consisting mostly of intertidal and near-shore forms. All species have been recorded as living both to the north and south of San Clemente Island, and have age ranges spanning the Pleistocene. Some, nevertheless, are probably reworked from the underlying Miocene rocks; these are indicated under "Fauna" below.

## MOLLUSCA

The small molluscan fauna obtained appears to be a mixture of several different life associations. All of the species live today in both protected and exposed coastal areas, except *Macoma secta* and *Saxidomus nuttalli* which are generally restricted to protected environments. All species are common in littoral zones except *Mitrella tuberosa* and *Epitonium indianorum* which live below the zone of heavy surf action. All of the species have Recent geographic ranges which include the latitude of San Clemente Island. Two species, *Epitonium indianorum* and *Lacuna carinata*, have ranges which end just south of San Clemente Island, and another one, *Haliotis fulgens*, is more abundant in the warmer waters off Baja California and is uncommon north of Point Conception, California.

## OSTRACODA

"At least 8 species of Ostracoda are present in the collection, six of which can be assigned to species previously recorded from the Pleistocene of southern California. One of these species, *Hermanites kawi*, is not reported as living. The remaining 5 species are known to be members of the Recent fauna and to include southern California in their living ranges. They all occur at Bahia Todos Santos, for which BENSON (1959) has given an account of the

distribution patterns of marine ostracods. The species at hand are members of BENSON's 'Biofacies I', which occurs on shallow bottoms of fine and medium sand at marine salinities around the northern margin of the bay and around Islas de Todos Santos and Punta Banda. Evidently the members of this biofacies have rather similar habitat preferences off Los Angeles (ROTHWELL, 1944, *vide* BENSON, 1959). The fossil collection most closely resembles associations from the outer parts of biofacies I, especially stations at Bahia Todos Santos where *Hemicythere californica* is rare or absent." (J. W. Valentine, *in litt.*)

#### OTHER INVERTEBRATES

The echinoid *Dendraster* lives today on sand or mud substrates subtidally or in protected tidal areas. The bryozoa are attached forms requiring a firm substrate.

#### PALEOECOLOGY

The difficulties of making paleoecologic interpretations of Pleistocene faunas at San Nicolas Island have been summarized by VEDDER & NORRIS (1963: p. 53) and these also apply to the interpretation of faunas from San Clemente Island. Nevertheless, some inferences are justified. The depositional environment can be inferred from the character of the sediments, the fauna, and the position of the locality with respect to the former shore line.

As evidenced by the topography and the configuration of the ancient shore line, deposition occurred in a small cove extending northward about  $\frac{3}{4}$  mile into the shore (see Figure 1b). On the west side of the cove a rocky, volcanic headland projected southward, and on the east the shore line gently curved southward. The headland apparently provided sufficient shelter from currents and wave action to create a semi-protected environment, which enabled the protected-coast elements to survive. The bottom of the cove was floored with sand and interspersed boulders. These sediments provided the substrates required for both the burrowing forms and rocky-shore elements. The sub-tidal species of mollusks and foraminifera indicate that deposition may have taken place below the surf zone, although shoreward transportation of such species may occur (VALENTINE, 1961: p. 348). These species, which commonly live below the zone of active surf, may have been able to move into water shallower than normal because of decreased wave action in this sheltered area. The fossil locality is 20 feet lower in elevation than the shore line angle indicating that the depth of water at the time of deposition was not more than about 20 feet.

All of the species found could be expected to live at San Clemente Island today. The several predominantly northern or southern elements in the fauna are not unusual for the Channel Islands, for these elements overlap in the region today because of hydrographic conditions which permit both warmer and cooler sea-surface temperatures locally than along the mainland (VALENTINE, 1961: p. 345). These elements in the fossil fauna suggest that similar conditions were existent during the life-time of the fauna.

#### AGE AND CORRELATION

Problems of age dating and correlation of marine terraces above sea level in California have been summarized by LIPPS (1964: p. 1174) and VEDDER & NORRIS (1963: pp. 52 - 53). These problems prevent definite correlations and dating of the San Clemente Island terrace at Horse Cove.

All fossils found, except *Hermanites kewi*, range in age from at least near the beginning of the Pleistocene to the present and thus are of no help in determining the age of the deposit. Most marine terraces above sea level on the mainland have been considered Upper Pleistocene because they truncate Lower Pleistocene beds tilted by the "Mid-Pleistocene orogeny". This appears not to be true for all terraces on the northern Channel Islands, where VALENTINE & LIPPS (1963) interpreted a fauna recovered from a 250-foot terrace as probably of Early Pleistocene age, and where ORR (1960) and LIPPS (1964) believed terraces at 100 feet and lower to be of Sangamon or younger age. On San Nicolas Island, faunas from higher terraces contain species (see VEDDER & NORRIS, 1963: table 4) which on the mainland are believed to be Pliocene or Early Pleistocene in age. Thus there seems to be significant age difference between terraces 100 feet and lower and those at higher elevations (see VALENTINE & LIPPS, *in press*). The only recorded fauna from higher terraces on San Clemente (COCKERELL, 1939) is essentially a rocky-shore assemblage without any Early Pleistocene or older elements. However, the small size of this collection (33 species) and the general lack of information concerning the nature of Early Pleistocene rocky-shore faunas does not preclude an Early Pleistocene age for COCKERELL's fauna. All known island terrace faunas at lower elevations contain no extinct elements. It has been suggested that the lower terraces may have formed during stands of sea level higher than at present, and that they may be correlative (EMERY, 1960: p. 8).

## FAUNA

All identified species and specimens referred to genera are listed below, together with references to their original description and present generic assignment. The classification of the Foraminiferida follows LOEBLICH & TAPPAN (1964) with certain modifications, that of the Mollusca follows KEEN (1963), and that of the Ostracoda follows MOORE (1961). The Foraminiferida are illustrated in Text figures 3 and 4.

## FORAMINIFERIDA

## MILIOLIDAE (family)

*Quinqueloculina* cf. *Q. akneriana* D'ORBIGNY, 1846, Foraminifères fossiles du Bassin Tertiaire de Vienne (Autriche), Gide et Comp. (Paris), p. 290; plt. 18, figs. 16 - 21 [Figure 3, nos. 2 a, 2 b]

*Quinqueloculina angulostriata* CUSHMAN & VALENTINE, 1930, Contr. Geol. Stanford Univ., vol. 1, no. 1; p. 12; plt. 2, figs. 5 a - 5 c. [Figure 3, nos. 3 a, 3 b]

*Quinqueloculina microcostata* NATLAND, 1938, Univ. Calif., Scripps Inst. Oceano. Bull., Tech. Ser., vol. 4; p. 142; plt. 4, figs. 6 a - 6 c [Figure 3, nos. 1 a - 1 c]

## NODOSARIIDAE

*Lenticulina cushmani* (GALLOWAY & WISSLER) = *Robulus cushmani* GALLOWAY & WISSLER, 1927, Journ. Paleont., vol. 1, no. 1; p. 51; plt. 8, figs. 11 a, 11 b [Figure 3, nos. 11 a, 11 b]

## POLYMORPHINIDAE

*Oolina melo* D'ORBIGNY, 1839, Voyage dans l'Amérique méridionale, Foraminifères, vol. 5, prt. 5; p. 20; plt. 5, fig. 9 [Figure 3, nos. 8 a, 8 b]

## BOLIVINITIDAE

*Bolivina advena* CUSHMAN, 1925, Contr. Cushman Lab.

Foram. Research, vol. 1, prt. 2; p. 29; plt. 5, figs. 1 a, 1 b [Figure 3, nos. 5 a, 5 b]

*Bolivina* sp. [Figure 3, nos. 7 a, 7 b]

## ISLANDIELLIDAE

*Islandiella californica* (CUSHMAN & HUGHES). NØRVANG, 1958, Videnskab. meddel. fra Dansk Naturhist. For., Copenhagen, vol. 120; p. 29 = *Cassidulina californica* CUSHMAN & HUGHES, 1925, Contr. Cushman Lab. Foram. Research, vol. 1, prt. 1; p. 12; plt. 2, figs. 1 a - 1 c [Figure 3, nos. 9 a, 9 b]

## BULIMINIDAE

*Bulimina* sp. [Figure 3, nos. 4 a, 4 b]

## UVIGERINIDAE

*Trifarina hughesi* (GALLOWAY & WISSLER) = *Uvigerina hughesi* GALLOWAY & WISSLER, 1927, Journ. Paleont. vol. 1, no. 1; p. 76; plt. 12, figs. 5 a, 5 b [Figure 3, nos. 6 a, 6 b]

## DISCORBIDAE

*Rotorbinella campanulata* (GALLOWAY & WISSLER).

DOUGLAS & SLITER, 1965, Tulane Stud. Geol., vol. 3, no. 3; p. 153; plt. 1, fig. 1; plt. 6, fig. 6 = *Globorotalia campanulata* GALLOWAY & WISSLER, 1927, Journ. Paleont., vol. 1, no. 1; p. 58; plt. 9, figs. 14 a to 14 c [Figure 4, nos. 6 a - 6 c]. Two specimens identical with the original illustrations of *Rotalia turbinata* CUSHMAN & VALENTINE, 1930, were found in samples from Horse Cove, but DOUGLAS & SLITER (*op. cit.*) stated that this form is one end member of a normal population of *Rotorbinella campanulata*.

*Valvulineria* cf. *V. glabra* CUSHMAN, BANDY & ARNAL, 1957, Amer. Assoc. Petrol. Geol. Bull., vol. 41, no. 9; p. 2053 = *Valvulineria vilardeboana* var. *glabra* CUSHMAN, 1927, Univ. Calif., Scripps Inst. Oceano. Bull., Tech. Ser., vol. 1, no. 10; p. 161; plt. 4, figs. 5, 6 [Figure 4, no. 4]. Miocene?

## Figure 3

Foraminifera from the Pleistocene at Horse Cove (UCLA 4936), San Clemente Island, California.

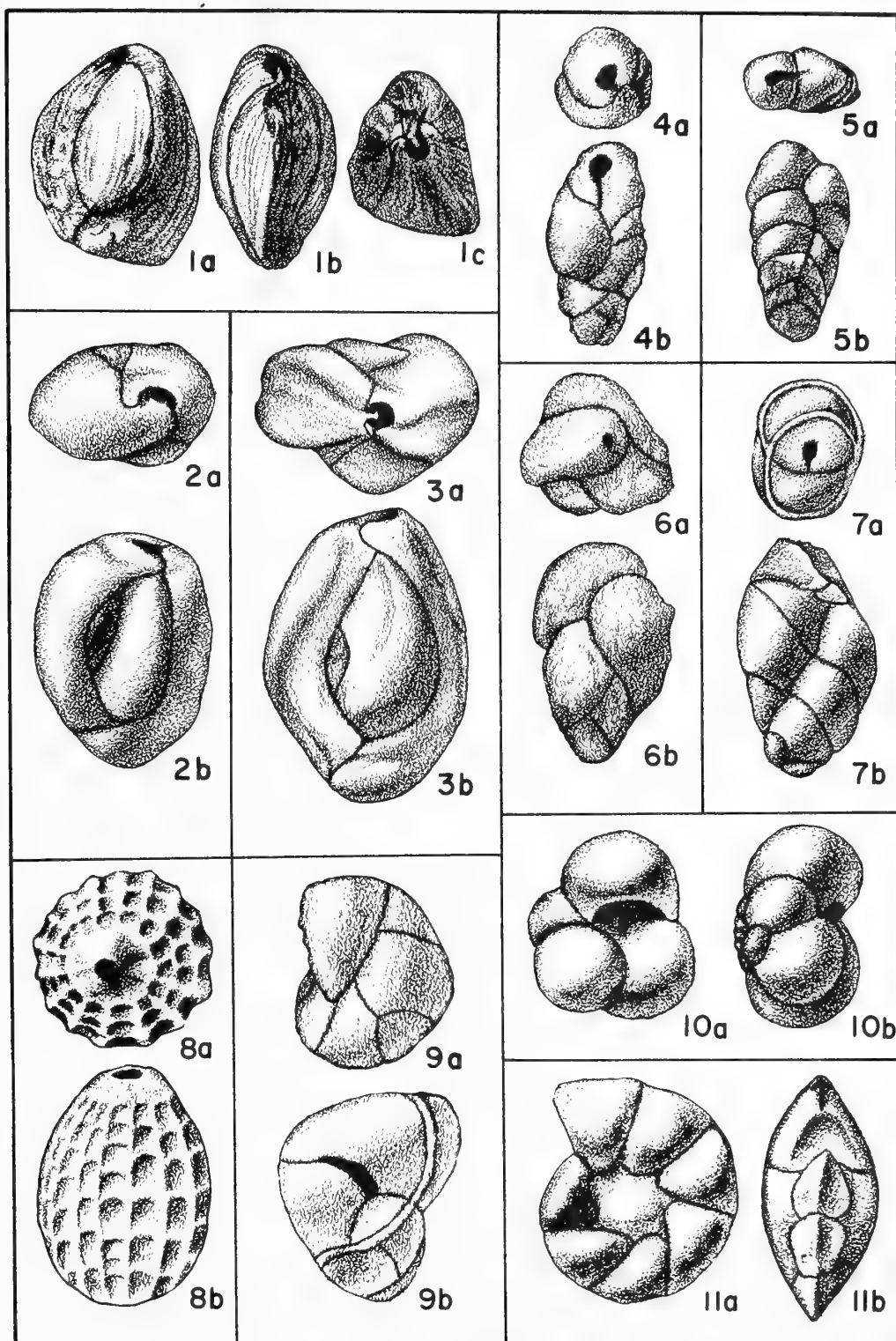
1. *Quinqueloculina microcostata* NATLAND. a: side view; b: edge view; c: apertural view. UCLA Hypotype 34143. x 70. 2. *Q. cf. Q. akneriana* D'ORBIGNY. a: apertural view; b: side view. UCLA figured specimen 34141. x 100. 3. *Q. angulostriata* CUSHMAN & VALENTINE. a: apertural view; b: side view. UCLA Hypotype 34142. x 70. 4. *Bulimina* sp. a: apertural view; b: side view. UCLA figured specimen 34148. x 140. Miocene? 5. *Bolivina advena* CUSHMAN. a: apertural view; b: side view. UCLA Hypotype 34147. x 100. 6. *Trifarina hughesi* (GALLOWAY & WISSLER). a: apertural view; b: side view. UCLA Hypotype 34149. x 100.

7. *Bolivina* sp. a: apertural view; b: side view. UCLA figured specimen 34146. x 140. Miocene? 8. *Oolina melo* D'ORBIGNY. a: apertural view; b: side view. UCLA Hypotype 34145. x 215.

9. *Islandiella californica* (GALLOWAY & WISSLER). a: side view; b: apertural view. UCLA Hypotype 34150. x 195. 10. *Globigerina bulloides* D'ORBIGNY. a: umbilical view; b: side view. UCLA Hypotype 34155. x 100. 11. *Lenticulina cushmani* (GALLOWAY & WISSLER). a: side view; b: apertural view. UCLA Hypotype 34144.

x 100.





## GLABRATELLIDAE

*Glbratella* sp. [Figure 4, nos. 7a - 7c]. Most species of *Glbratella* have been previously assigned to other genera and little attention has been given to the distinguishing umbilical characters (see SEIGLIE & BERMUDEZ, 1965), thus specific identification is not now possible.

## ELPHIDIIDAE

*Criboelphidium poeyanum* (D'ORBIGNY). LOEBLICH & TAPPAN, 1964, Treatise Invert. Paleont., Prt. C, Protista 2; p. C635. = *Polystomella poeyana* D'ORBIGNY, 1859, Foraminifères in DE LA SAGRA, Histoire Physique et Naturelle de l'Île de Cuba, Paris, p. 55. [Figure 4, nos. 8a, 8b]. BANDY (1963) listed 5 described species as subspecies of *C. poeyanum*, as NATLAND (1950: p. 15) first suggested, and showed that they all occurred in the same environments. As there is no apparent ecologic difference between these subspecies listed by BANDY, and as they seem to intergrade in morphology, they are considered variants of a single species.

## GLOBIGERINIDAE

*Globigerina bulloides* D'ORBIGNY, 1826, Ann. Sci. Nat. Paris, ser. 1, vol. 7; p. 277 [Figure 3, nos. 10a, 10b]

## ROSALINIDAE

The genus upon which this family is based, *Rosalina*, has bilamellar rather than monolamellar septa, hence it and its family was removed from the Discorbacea by DOUGLAS & SLITER (1965).

*Rosalina globularis* D'ORBIGNY, 1826, Ann. Sci. Nat. Paris, ser. 1, vol. 7; p. 271; plt. 13, figs. 1 - 4 [Figure 3, nos. 2a - 2c]. DOUGLAS & SLITER (1965) have shown

that various species originally described from the west coast of North America are conspecific with D'ORBIGNY's species.

## CIBICIDIDAE

*Cibicides fletcheri* GALLOWAY & WISSLER, 1927, Journ. Paleont., vol. 1, no. 1; p. 64; plt. 10, figs. 8a - 9c. [Figure 4, nos. 1a - 1c, 3a - 3c]

## NONIONIDAE

*Pullenia miocenica* KLEINPELL, 1938, Miocene stratigraphy of California, Tulsa, p. 338; plt. 14, fig. 6 [Figure 4, nos. 5a, 5b]. Miocene?

## GASTROPODA

## HALIOTIDAE

*Haliotis fulgens* PHILIPPI, 1845, Zeitschr. für Malakozool., p. 150

*Haliotis rufescens* SWAINSON, 1822, Cat. Shells Bligh, appendix, p. 2

## TROCHIDAE

*Calliostoma supragranosum* CARPENTER, 1864, British Assoc. Adv. Sci. Reprt. for 1863, p. 653

## EPITONIIDAE

*Epitonium indianorum* (CARPENTER). DALL, 1917, U. S. Nat. Mus., Proc., vol. 53, no. 2217, p. 477 = *Scalaria indianorum* CARPENTER, 1864, Brit. Assoc. Adv. Sci., Reprt. for 1863, p. 660

## LACUNIDAE

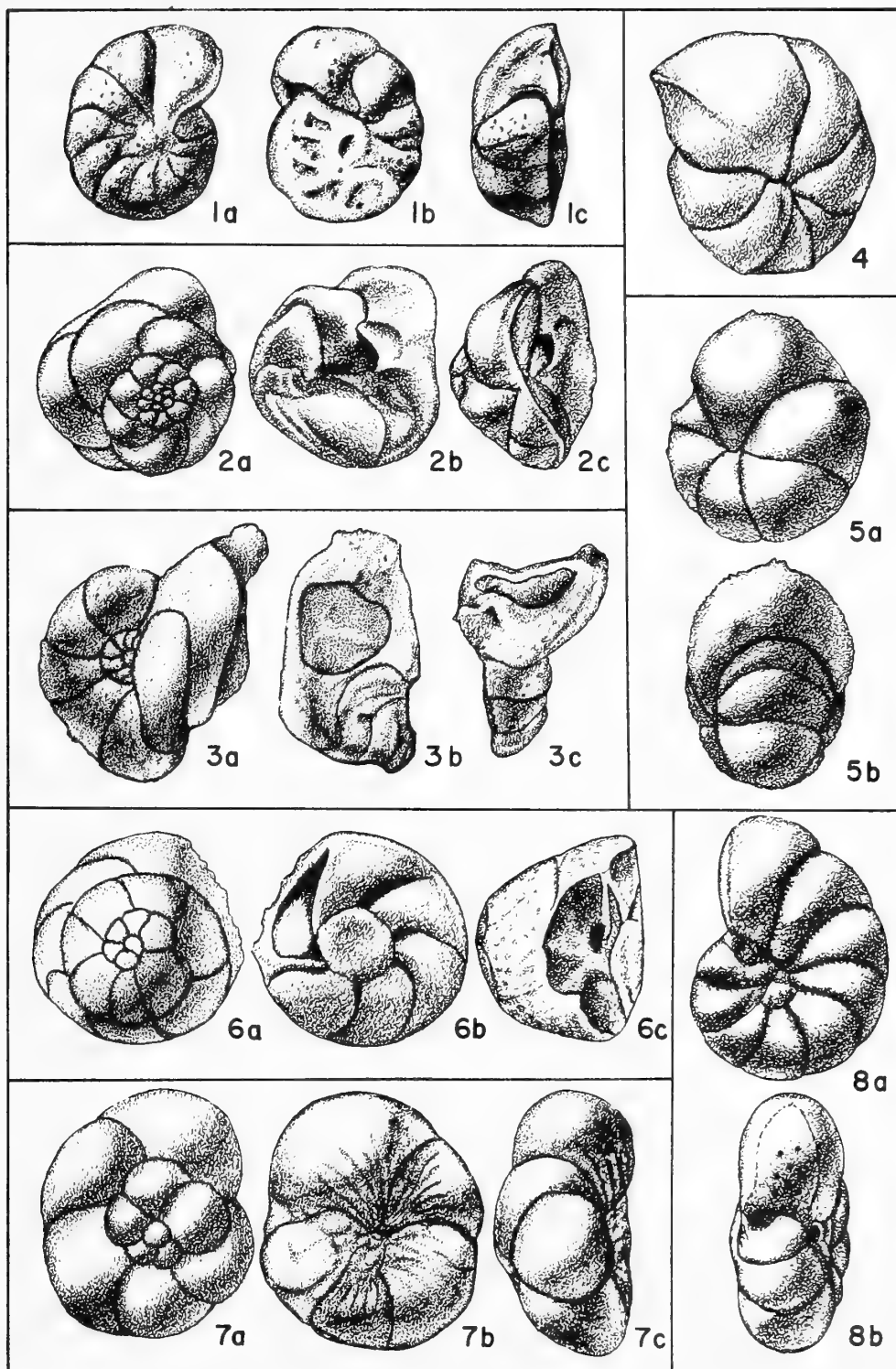
*Lacuna carinata* GOULD, 1849, Boston Soc. Nat. Hist., Proc., vol. 3, p. 75

## Figure 4

Foraminifera from the Pleistocene at Horse Cove (UCLA 4936), San Clemente Island, California.

1. *Cibicides fletcheri* GALLOWAY & WISSLER. a: spiral view; b: umbilical view; c: apertural view. UCLA Hypotype 34159. x 100.
2. *Rosalina globularis* D'ORBIGNY. a: spiral view; b: umbilical view; c: edge view showing aperture. UCLA Hypotype 34153. x 90.
3. *Cibicides fletcheri* GALLOWAY & WISSLER. The specimen is distorted because it was attached to a firm substrate during life. a: spiral view; b, c: edge views showing apertural opening from two views. UCLA Hypotype 34158. x 90.
4. *Valvulineria* cf. *V. glabra* CUSHMAN. Side view. UCLA Hypotype 34156. x 200. Miocene?
5. *Pullenia miocenica* KLEINPELL. a: side view; b: aper-

tural view. UCLA Hypotype 34157. x 140. Miocene? 6. *Rotorbinella campanulata* (GALLOWAY & WISSLER). This form has been called *Rotalia turbinata* CUSHMAN & VALENTINE. a: spiral view; b: umbilical view showing umbilical plug; c: apertural view. UCLA Hypotype 34151. x 140. 7. *Glbratella* sp. a: spiral view; b: umbilical view showing characteristic striations, which facilitate plasmogamic reproduction; c: edge view. UCLA figured specimen 34152. x 200. 8. *Criboelphidium poeyanum* (D'ORBIGNY). a: side view; b: apertural view, showing multiple openings characteristic of this genus. UCLA Hypotype 34154. x 90.



## CAECIDAE

- Caecum californicum* DALL, 1885, U. S. Nat. Mus., Proc., vol. 8, p. 541  
*Micranellum crebricinctum* (CARPENTER). BARTSCH, 1920, Journ. Washingt. Acad. Sci., vol. 10, p. 678 = *Caecum crebricinctum* CARPENTER, 1864, Brit. Assoc. Adv. Sci., Reprt. for 1863, p. 655

## VERMETIDAE

- Petalochonchus complicatus* DALL, 1908, Bull. Mus. Comp. Zool., Harvard, vol. 43, p. 326  
*Serpulorbis squamigerus* (CARPENTER). CARPENTER, 1864, Brit. Assoc. Adv. Sci., Reprt. for 1863, p. 557 = *Aletes squamigerus* CARPENTER, 1856, Zool. Soc. London, Proc., p. 226

## CERITHIIDAE

- Bittium armillatum* CARPENTER, 1864, Brit. Assoc. Adv. Sci., Reprt. for 1863; p. 655  
*Bittium* sp. One small fragment of a *Bittium* with spiral threads similar to *B. eschrichtii* (MIDDENDORFF) was found.

## CALYPTRAEIDAE

- Crepidula* sp.

## COLUMBELLIDAE

- Mitrella tuberosa* (CARPENTER). GRANT & GALE, 1931, San Diego Soc. Nat. Hist., Mem., vol. 1, p. 697; plt. 26, fig. 45 = *Amycla tuberosa* CARPENTER, 1864, Brit. Assoc. Adv. Sci., Reprt. for 1863, p. 662

## NASSARIIDAE

- Nassarius (Caesia) fossatus* (GOULD). ADDICOTT, 1965, U. S. Geol. Surv., Prof. Paper 503-B, explan. for plt. 2, figs. 5, 6 = *Buccinum fossatum* GOULD, 1849, Boston Soc. Nat. Hist., Proc., vol. 3, p. 152

## OLIVIDAE

- Olivella biplicata* (SOWERBY). SWAINSON, 1840, Treat. Malac., pp. 133, 322, text fig. 3 = *Oliva biplicata* SOWERBY, 1825, Cat. Shells Tankerville, app., p. 33

## CONIDAE

- Conus californicus* HINDS, 1844, Zool. Voy. Sulphur, vol. 2; p. 7; plt. 1, figs. 3-5

## PELECYPODA

## LUCINIDAE

- Lucina californica* CONRAD, 1837, Journ. Acad. Nat. Sci., Philadelphia, vol. 7, p. 255; plt. 20, fig. 1

## VENERIDAE

- Transennella tantilla* (GOULD). DALL, 1902, U. S. Nat. Mus., Proc., vol. 26, p. 384 = *Venus tantilla* GOULD, 1853, Boston Journ. Nat. Hist., vol. 6, p. 406; plt. 15, fig. 10  
*Saxidomus nuttalli* CONRAD, 1837, Journ. Acad. Nat. Sci., Philadelphia, vol. 7, p. 249; plt. 19, fig. 12

## MACOMIDAE

- Macoma secta* (CONRAD). H. & A. ADAMS, 1858, Genera Rec. Moll., vol. 2, p. 301 = *Tellina secta* CONRAD, 1837, Journ. Acad. Nat. Sci., Philadelphia, vol. 7, p. 257

## OSTRACODA

## CYTHERELLIDAE

- Cytherella (Cytherelloidea)* sp. A single immature valve, with much coarser pits than those on *C. (C.) californica* LEROY, was found.

## BRACHYCYTHERIDAE

- Brachycythere lincolniensis* LEROY, 1943, Journ. Paleont., vol. 17, no. 4, p. 364; plt. 61, figs. 1-5, plt. 62, figs. 1, 2; text fig. 21 m

## CYTHERURIDAE

- Hemicytherura* cf. *H. clathrata* (SARS). BENSON, 1959, Univ. Kansas, Paleont. Contr., Arthropoda, art. 1, p. 54; plt. 4, fig. 7 d; plt. 7, fig. 2; plt. 9, fig. 3

## HEMICYTHERIDAE

- Urocythereis glauca* (SKOGSBERG) = *Cythereis glauca* SKOGSBERG, 1928, Calif. Acad. Sci., Proc., vol. 15, p. 110; plt. 3, figs. 2, 6, 7; plt. 6, fig. 4; text fig. 19. HAZEL (1962) noted that this species should be referred to *Urocythereis*.  
*Hemicythere jollaensis* LEROY, 1943, Journ. Paleont., vol. 17, no. 4, p. 365; plt. 59, figs. 28-33; plt. 62, figs. 15, 16; text fig. 2 q  
*Hemicythere palosensis* LEROY, 1943, Journ. Paleont., vol. 17, no. 4, p. 365; plt. 60, figs. 14-18; text fig. 2 c  
*Caudites?* sp. An articulated pair of immature valves resembling *Caudites* in external shape but with less pronounced sculpture for that genus is present in the collections from Horse Cove.

## TRACHYLEBERIDIDAE

- Hermanites kewi* (LEROY). BOLD, 1953, Micropaleont., vol. 3, no. 3, p. 240 = *Cythereis kewi* LEROY, 1943, Journ. Paleont., vol. 17, no. 4, p. 369; plt. 60, figs. 24-27; plt. 62, figs. 9, 10; text fig. 2 d. This species

is known from Pliocene and Lower Pleistocene deposits of southern California, and from the Lower Miocene (?) in Trinidad (BOLD, 1957). It has not been reported to be living.

## ECHINODERMATA

### CLYPEASTEROIDA (class)

*Dendraster* sp. A small fragment, probably of *D. excentricus* (ESCHSCHOLTZ), was found at the Horse Cove locality.

### CENTRECHINOIDA

*Strongylocentrotus* sp. Spines and plates, referable to this genus, are abundant in the deposit.

## MAMMALIA

### CETACEA (order)

A single left delphinid periotic, resembling those of species of the genus *Lissodelphis* (E. D. Mitchell, personal communication), was found.

## LOCALITY DESCRIPTION

UCLA 4936 is at the head of a small tributary trending northwest from Horse Creek, approximately 1425 feet N19°W of the mouth of Horse Creek, San Clemente Island, Los Angeles County, California. USGS San Clemente Island, South Quadrangle, 1950 edition. Collected by Jere H. Lipps and Edward D. Mitchell, Jr., September 7, 1961. JHL 130-61.

## ACKNOWLEDGMENTS

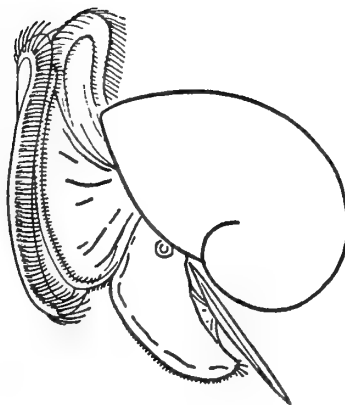
I thank the U. S. Naval Ordnance Test Station, Pasadena Annex, for permitting field work on San Clemente Island and for making facilities available to me. E. D. Mitchell, Jr., Arctic Biological Station, Fisheries Research Board of Canada, Montreal, provided much field assistance, and he and J. W. Valentine, University of California, Davis, studied the cetacean and ostracod fossils respectively, and supplied information contained in this report. H. T. Loeblich and K. E. Lipps, University of California, Los Angeles, and E. D. Mitchell, Jr. and J. W. Valentine read the manuscript at various stages of preparation. J. L. Inge illustrated

the foraminifera. This study was supported by an AAAS Research Grant administered by the Southern California Academy of Sciences. This report is the result of studies of the paleontology and geology of the California Channel Islands assisted by the Los Angeles County Museum.

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## Systematic Implications of Radular Structures of West Coast Species of *Tegula*

BY

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(Plates 54 and 55; 2 Text figures)

GASTROPOD RADULAE have been used by numerous workers as tools for determining relationships. Acceptance of radulae as keys to relationships and as diagnostic characters has not, however, been unquestioned. GRANT (1933) contended that radulae do not provide reliable characters because they bear the stress of contact with the environment and are, therefore, subject to rapid convergent and divergent evolution. CARRIKER (1943), working with *Lymnaea stagnalis appressa* SAY, and HOWE (1930), working with members of the Pleuroceratidae, found sufficient variability in the denticular pattern to cast doubt on the reliability of the radula for specific diagnosis.

A major objective of this study has been an examination of the value of radular structures as an aid to the clarification of intrageneric relationships, using 9 species of *Tegula* from the west coast of North America.

The history of the taxonomy of *Tegula* is a tortuous one. The first west coast species described, or sometimes figured and named but not described, were assigned to *Trochus*. Subgenera were proposed from time to time, two being *Omphalius* and *Chlorostoma*. These were later used as genus names under which several species were described. Still later those became subgenera in *Tegula*. Since *Tegula* has not been monographed many unresolved contradictions in taxonomy and indicated relationships remain.

OLDROYD (1927) placed *Tegula funebris*, *T. gallina*, *T. brunnea*, *T. montereyi* and *T. rugosa* in the subgenus *Chlorostoma*; *T. pulligo* in the subgenus *Promartynia* (as proposed by DALL, 1909); and *T. aureotincta* and *T. mariana* in the subgenus *Omphalius*.

GRANT & GALE (1931) retained *Tegula funebris* and *T. gallina* in the subgenus *Chlorostoma*, but they believed that *T. brunnea* belonged with *T. aureotincta* in the sub-

genus *Omphalius*. They accepted the subgenus, however, as doubtful when based on shell characters alone.

KEEN (1958) placed *Tegula rugosa* as the only west coast member of the subgenus *Omphalius*. She contends that an early misinterpretation of the type species lead to the misuse of *Omphalius* for a series of *Tegula* species which she places under the subgenus *Agathistoma* which includes one animal considered in this study, *T. mariana*.

Only FRITCHMAN (1965) has suggested relationships based on radular structure. He placed together *Tegula pulligo*, *T. aureotincta*, *T. brunnea* and *T. montereyi*. *Tegula gallina* and *T. funebris* were placed in another group. Four other *Tegula* were grouped together with *T. mariana* and *T. eiseni* considered to be closely related and with *T. rugosa* and *T. regina* as less closely related. FRITCHMAN did not consider subgeneric groupings but simply stated that the radulae of certain species were more like each other than those in other groups.

### PREPARATION OF RADULAE

Each snail was removed from its shell and placed in a caustic solution. The radula was removed according to the method used by FRITCHMAN (1960). Following extraction, the radulae were stained either with aceto-carmin or fast green and then mounted tooth-side up, either as whole mounts or, following VERDCOURT (1948), some radulae were teased to obtain isolated teeth after being placed in Canada balsam.

The stainability of the teeth changes along the length of the radula as found by RAVEN (1958). Fortuitously, that portion of the radula which stained most distinctly was just anterior to the area of proliferation where the teeth show features which are later worn down in older teeth. This area was the one which was utilized for critical study.

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## PHOTOMICROGRAPHS

Photomicrographs were prepared from the slides for comparison of radular structures. On comparison of *Tegula pulligo* (Plate 54, Figure 1) with other *Tegula* species, the radula was found to be quite dissimilar. The extent of difference would confirm DALL's erection of a separate subgenus, *Promartynia*, for this species. *Tegula pulligo* is primarily found off-shore on kelp while the rest of the *Tegula* species are chiefly found scraping algal film from rocks (SMITH & GORDON, 1948). Consideration of the shell shows that it is not radically different from other *Tegula* species. This lends support to the expectation that the radula might undergo edaphic evolution resulting in quite distinctive radular structure in an animal whose shell evolved more conservatively.

The great similarity of the laterals, especially the fifth laterals, of *Tegula aureotincta* and *T. brunnea* (Plate 54, Figures 2 and 3) would seem to lend credibility to the standing of *Omphalius*. The position of *Chlorostoma* would seem to be substantiated by the close similarity between *T. funebris* and *T. gallina*. Both possess a dorso-lateral recurved process on the fifth lateral (Plate 54, Figure 4 and Plate 55, Figure 5). Thus, the subgeneric groupings as understood by GRANT & GALE (1931) are supported by this study.

*Tegula eiseni* and *T. mariana* would seem to be closely related on the basis of commonality in: obtuse blades on the lateral teeth; all round marginal teeth; a "beaked" dorsal horizon line where the cusp joins the stem of the fifth lateral (Plate 55, Figures 6 and 7). This is in agreement with FRITCHMAN's (1965) suggested grouping.

*Tegula rugosa* (Plate 55, Figure 8) appears to stand alone in radular features. This would seem to confirm KEEN's (1958) placement of it in a separate subgenus.

*Tegula montereyi*, in accord with FRITCHMAN (1965), was found to be variable in radular structure. This variability suggests that this organism warrants further study before its systematic placement is determined.

It was concluded that denticular patterns on the radula provide an adequate means for deducing intrageneric

relationships for 8 of the 9 *Tegula* species considered, *T. montereyi* being the exception.

## CRITIQUE OF FRITCHMAN'S METHODS

FRITCHMAN's (1965) suggested intrageneric relationships were based, in part, on a consideration of the following data and on a numerical treatment of the length/width ratio of the central tooth expressed as a per cent. The slides were examined microscopically and the following information was recorded for each: the character of the lateral teeth (pointed or blunt); the point where the marginal teeth serrations begin; where the serrations become complete; and, the length and width of the central tooth measured in micra.

The range of his ratios was graphed and the range of the ratios obtained in this study was graphed beside his (Text figure 1). It was seen that the addition of as few as 3 samples to his might greatly alter the range of ratios for a given species and that the ranges of data overlap. He also placed emphasis on the average of the ratios. However, a consideration of all the averages proved essentially meaningless.

Still another character used by FRITCHMAN was that of noting the point of conversion of the tip of the marginal teeth from pointed to round. It was quite clear that some teeth were pointed and that others, later in the row, were round. The conversion in some species is very gradual and determining what tooth should be termed round was highly subjective. The ranges of these data, which overlap, were also graphed (Text figure 2).

FRITCHMAN utilized two other characters of the marginal teeth: the point where serrations begin and the point where the serrations are complete. The use of these properties poses practical difficulties as the radula has a tendency to curl and in so doing may turn the teeth out of view. The problem is not easily overcome since critical counts may reach 25 teeth before serrations are complete and they may be as small as  $3\mu$  across the base where they join the tooth. Of the 50 *Tegula* examined, only 28 could be seen well enough to obtain these data. An attempt

## Explanation of Plate 54

Figure 1: *Tegula pulligo* (x 204) - Showing the fringed aspect of the third, fourth and fifth lateral.

Figure 2: *Tegula aureotincta* (x 204) - Portion of a radular row showing the fifth lateral (arrow).

Figure 3: *Tegula brunnea* (x 204) - Portion of a radular row showing the fifth lateral (arrow).

Figure 4: *Tegula funebris* (x 204) - Portion of a radular row showing the third, fourth and fifth lateral. Note the dorso-lateral recurved process (arrow).



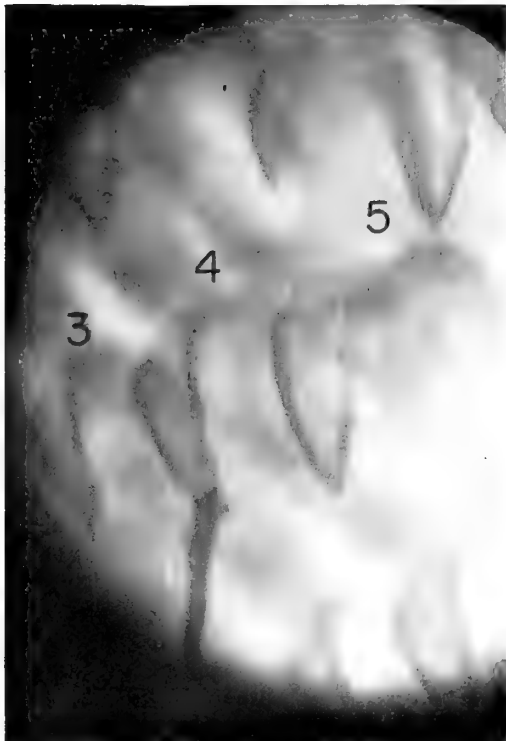


Figure 1

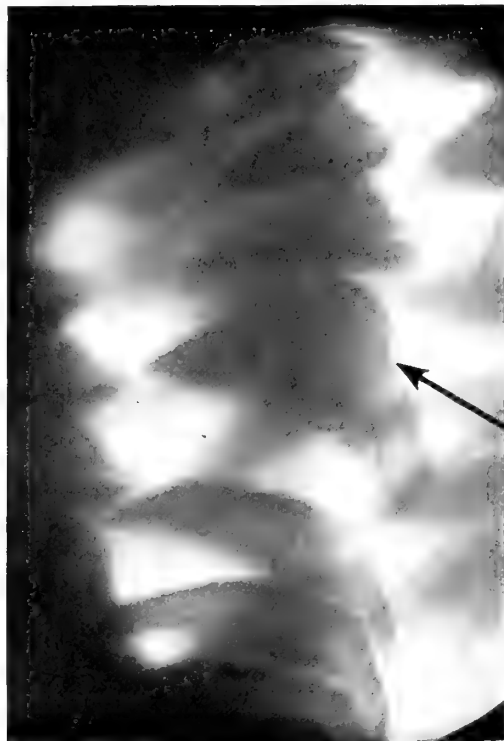


Figure 2



Figure 3

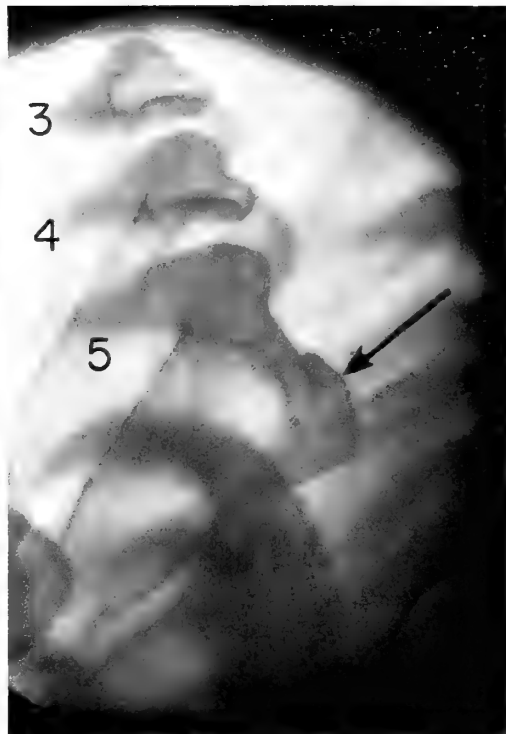


Figure 4



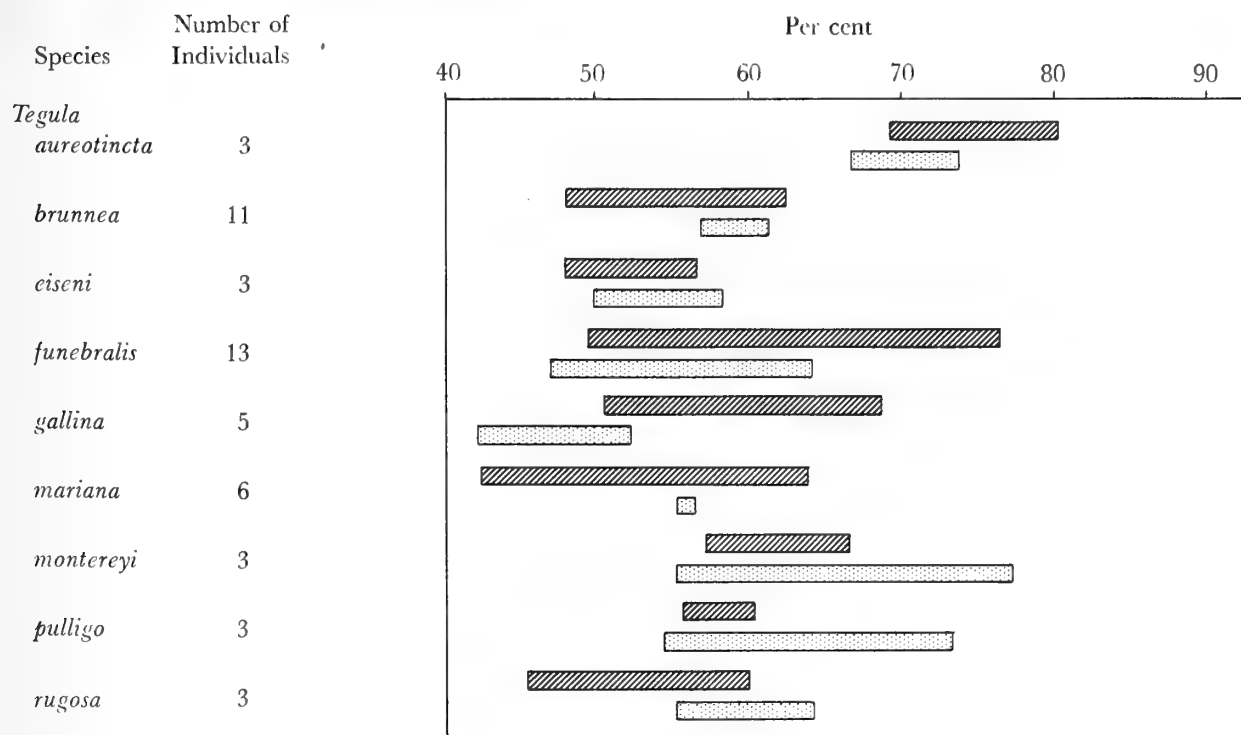


Figure 1

Range of Central Tooth Length/Width Ratios

FRITCHMAN

MERRIMAN

was made to graph them but the result was not subject to interpretation.

A consideration of the graphs and of the other data obtained by measuring and counting techniques lead to the conclusion that these are not valid devices for determining systematic placement of *Tegula*.

### CORRELATION STUDY

HOWE (1930) suggested that radula studies include the size of the shell as part of the requisite data. Accordingly, every shell was measured from the upper margin of the lip to the apex and from the upper margin of the lip to the farthest body whorl. A correlation study was made utilizing shell size and central tooth length and width. The simple correlation,  $r$ , was found using the formula (MOS-TELLER, 1961):

$$r = \frac{(x_1 - \bar{x})(y_1 - \bar{y})}{NS.S_v}$$

Results involving only 3 specimens were disregarded as being a statistically unreliable sample. According to FRANK (1965), the shell width is inherently subject to less measurement error. Therefore, only data for samples larger than 3 and correlations utilizing shell width were considered as meaningful.

Examination of these data showed inconsistencies since three species, *Tegula brunnea*, *T. funnebralis*, and *T. rugosa*, showed negative correlations implying an inverse relationship between shell and central tooth dimensions while the balance of the correlations for these and the other species considered were positive, indicating a direct relationship.

Considering that  $r^2$  = the proportion of variances in Y predictable from or attributable to variations in X, it was possible to determine the relationship between shell size and central tooth measurements for all *Tegula* specimens studied (50 individuals). The square of the correlation coefficients indicated that 50% and 58% of the time the shell width and tooth size were related while the

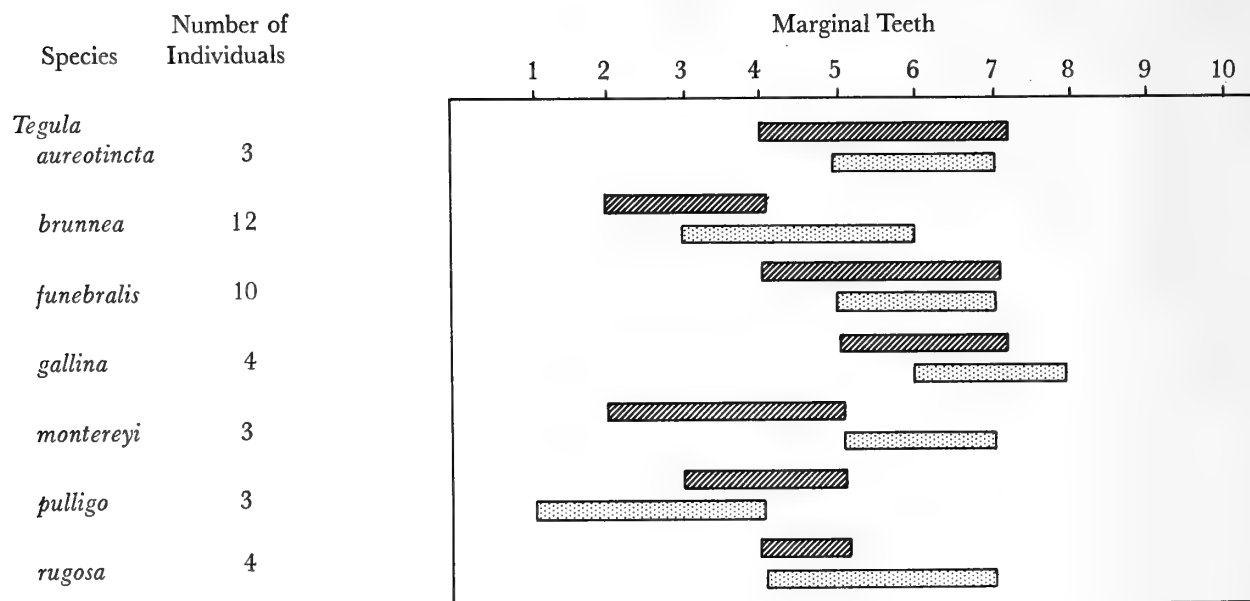


Figure 2

Range of Marginal Teeth Conversion from Pointed to Round

FITCHMAN

MERRIMAN

balance of the time there was no apparent relationship. Therefore, it is the investigator's opinion that the time consuming process of shell measurements could be eliminated in future radular studies of *Tegula*.

#### ATYPICAL DENTICULAR PATTERNS

Because of the findings of CARRIKER (1943) and HOWE (1930) all radulae were examined for atypical denticular patterns. It appears that aberrations are rare and that they are obvious as aberrations so that such specimens may be readily eliminated from consideration when they occur.

#### SUMMARY

Denticular patterns on the radula provided an adequate means for deducing intrageneric relationships and clarified subgeneric standings for: *Tegula pulligo*, *T. aureotincta*, *T. brunnea*, *T. funnebralis*, *T. gallina*, *T. eiseni*, *T. mariana*, and *T. rugosa*. Variability in the radula of *T. montereyi* suggests that it warrants further study before systematic placement is determined.

A method for determining intrageneric relationships based on measuring and counting various radular structures was not supported by this research.

#### Explanation of Plate 55

Figure 5: *Tegula gallina* (x 204) - The fifth lateral with a dorso-lateral recurved process (arrow).

Figure 6: *Tegula eiseni* (x 204) - The fifth lateral standing between two rows of all round marginal teeth. Note the small "beak" (arrow) on the fifth lateral.

Figure 7: *Tegula mariana* (x 204) - Showing the fifth lateral with an irregularly curved dorsal shape with a "beak" (arrow).

Figure 8: *Tegula rugosa* (x 204) - The fifth lateral showing an elongate curving dorsal line (arrow). The blade is fading into another focal plane.



Figure 5

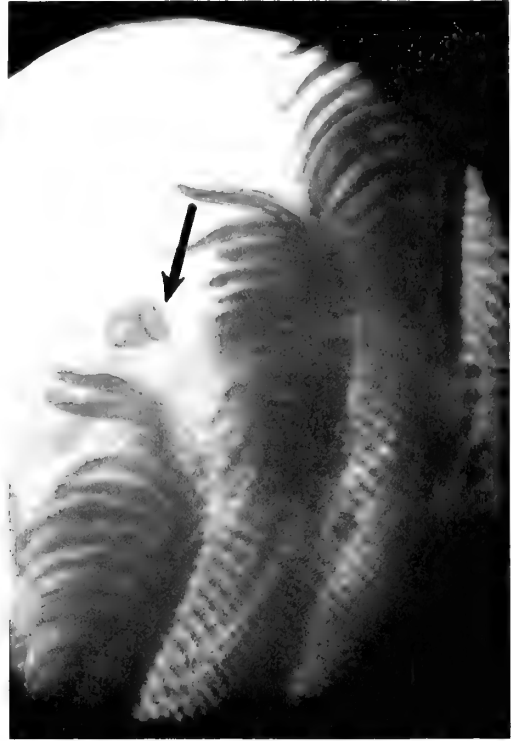


Figure 6

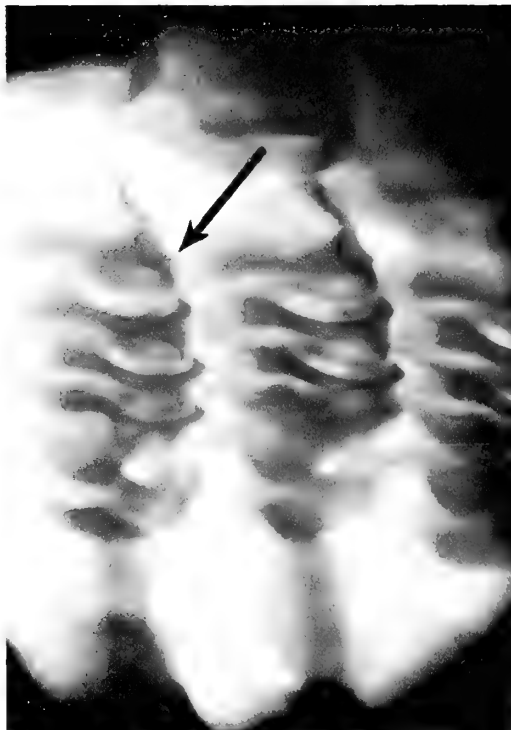


Figure 7

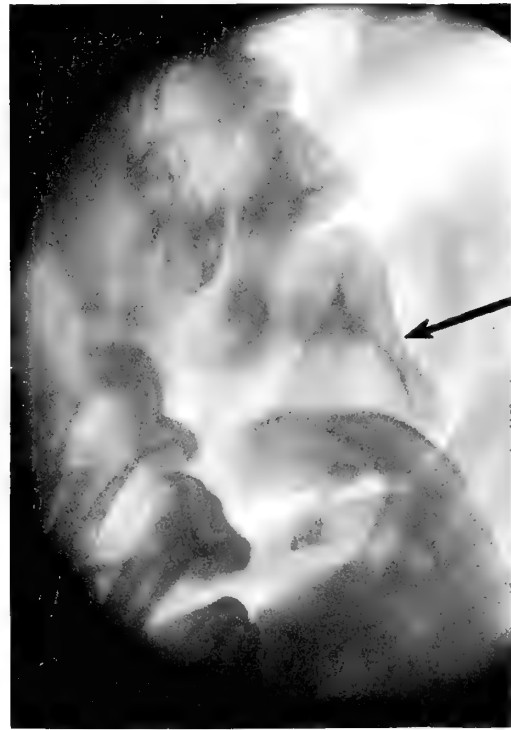


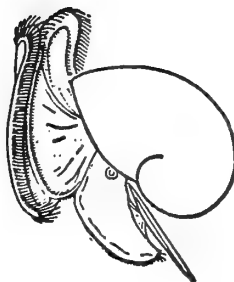
Figure 8



A correlation study of the size of shell and the size of the central radular tooth showed a low correlation contradicting the suggestion that radula studies include the size of the shell as requisite data.

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## West American Scissurellidae

BY

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(Plate 56)

WEST AMERICAN SCISSURELLIDAE have not previously been reviewed. New records and innovations in the systematics of the west American species are offered, based on the review of the family in my dissertation (McLEAN, 1966).

### ACKNOWLEDGMENTS

I am grateful to Professors A. Myra Keen, Rolf Bolin and Donald P. Abbott of Stanford University for criticism of the dissertation manuscript. In addition, Dr. Keen has provided information about type specimens in the British Museum (Natural History) (BMNH). Drs. Harald A. Rehder and Joseph Rosewater were most helpful during my visits to the United States National Museum (USNM). Specimens of two Alaskan species were kindly loaned by Mr. Rae Baxter and Mr. Robert Talmadge. British Columbian specimens were loaned by Dr. I. McT. Cowan and Californian specimens by Dr. S. Stillman Berry. Photographs have been taken by Dr. Keen, Perfecto Mary, and Mike Hatchimonji. This investigation was supported (in part) by fellowship number 18613, Division of General Medical Sciences, U. S. Public Health Service.

### SCISSURELLIDAE

**Diagnosis:** Shell small, porcelainous except for thin nacreous layer within; with few rapidly increasing whorls; turbate to depressed, umbilicate, often with reticulate sculpture. Outer lip with slit or foramen; operculum round, multispiral, with central nucleus.

The radula has a broad, cusped rachidian tooth, typically five cusped lateral teeth, and numerous serrate marginal teeth. The first four lateral teeth have broad basal areas; the fifth lateral is larger and more broadly cusped than the others (THIELE, 1929).

The Scissurellidae are small, white-shelled forms, generally living in sublittoral to abyssal depths. Species occur in tropical, temperate, and cool-water provinces.

Although out of date, the only comprehensive treatment of world Scissurellidae is that of PILSBRY in the Manual of Conchology (1890). The Japanese species have been reviewed by HABE (1951).

Two genera are represented in the west American fauna, *Scissurella* ORBIGNY, and *Sinezona* FINLAY.

### Key to the West American Genera of Scissurellidae

1. Outer lip with an open slit ..... *Scissurella*  
Outer lip with single perforation ..... *Sinezona*

### *Scissurella* ORBIGNY, 1824

*Scissurella* ORBIGNY, 1824, p. 340. Type species by SD of GRAY, 1847, *Scissurella laevigata* ORBIGNY, 1824. Recent, Mediterranean. PILSBRY, 1890 (1888 - 1898), vol. 12, p. 49; plt. 50, figs. 1 - 2.

**Diagnosis:** Shell with open slit on outer lip, producing a selenizone.

Two subgenera of *Scissurella* were recognized by KEEN in MOORE (1960): *Scissurella* s. str., and *Anatoma* WOODWARD. The former, not represented on the western coast of North America, shows a flattened spire, with the selenizone on the upper half of the whorl. The subgenus *Anatoma* is represented by 4 species in the northeastern Pacific. None are recorded from the Panamic or Peruvian Provinces.

### (*Anatoma*) WOODWARD, 1859

*Anatoma* WOODWARD, 1859, p. 204. Type species, by M, *Scissurella crispata* FLEMING, 1828.

**Diagnosis:** Spire somewhat elevated, selenizone on central portion of whorl; sculpture cancellate.



*Anatoma* WOODWARD is not an emendation of *Anatomus* MONTFORT, 1810, by explicit statement of WOODWARD. However, because many recent authors have been confused by the similarity of names they have erroneously used *Schizotrochus* MONTEROSATO, 1877, an objective synonym.

DALL (1921) listed two species of *Scissurella*: *S. kelseyi* DALL and *S. chiricova* DALL; both are here considered as synonyms of *S. crispata* FLEMING, a species widely distributed in the North Atlantic and North Pacific. Reported here as living representatives of the west American fauna for the first time are three additional species; *S. lyra* BERRY, previously known only from the early Pleistocene of southern California, *S. lamellata* (A. ADAMS), and *S. soyoae* (HABE) both previously known from Japan.

#### Key to the West American Species of *Scissurella* (*Anatoma*)

1. Edges of slitband sharply raised ..... 2  
Edges of slitband not sharply raised ..... *S. (A.) soyoae*
2. Axial and spiral sculpture of equal magnitude ..... 3  
Axial reticulations more pronounced than spiral  
ridges ..... *S. (A.) lamellata*
3. Spire elevated ..... *S. (A.) crispata*  
Spire depressed ..... *S. (A.) lyra*

#### *Scissurella* (*Anatoma*) *crispata* FLEMING, 1832

(Plate 56, Figures 1 to 4)

*Scissurella crispata* FLEMING, 1832, p. 385; plt. 6, fig. 3. FORBES & HANLEY, 1850 (1848-1853), vol. 2, p. 544; plt. 63, fig. 6. - JEFFREYS, 1865 (1862-1869), vol. 3, p. 283. - SARS, 1878, p. 126; plt. 8, fig. 7 [shell]; plt. III, fig. 4 [radula]. - PILSBRY, 1890 (1888-1898), vol. 12, p. 52; plt. 65, figs. 22-25; vol. 11, plt. 50, fig. 18 [radula, copy SARS]. - ODHNER, 1912, pp. 13, 36; plt. 2, figs. 25-27. - THIELE, 1929, p. 30, fig. 16. - FRETTER & GRAHAM, 1962, p. 488, figs. 255, 256 [animal]. - CLARKE, 1962, p. 6.

*Scissurella aspera* PHILIPPI, 1844, p. 160; plt. 25, fig. 17. - JEFFREYS, 1865 (1862-1869), vol. 3, p. 285 [under *S. crispata*].

*Scissurella crispata* var. *aspera* PHIL. - ODHNER, 1912, p. 13; plt. 2, fig. 25.

*Scissurella angulata* LOVÉN, 1846, p. 152. - JEFFREYS, 1865 (1862-1869), vol. 3, p. 285 [under *S. crispata*].

*Scissurella crispata* var. *angulata* LOV. - PILSBRY, 1890 (1888-1898), vol. 12, p. 52. - ODHNER, 1912, p. 13; plt. 2, figs. 26, 27.

*Anatomus japonicus* A. ADAMS, 1862, p. 347. - PILSBRY, 1890 (1888-1898), vol. 12, p. 59 [copy ADAMS]. - HABE & KOSUGE, 1964, p. 4.

*Schizotrochus japonicus* (A. AD.). - HABE, 1951, p. 65; plt. 11, fig. 9. - 1961, p. 2; plt. 1, fig. 7.

*Scissurella japonica* (A. AD.). - KURODA & HABE, 1952, p. 84.

*Anatoma japonica* (A. AD.). - HABE, 1964, p. 2; plt. 1, fig. 7.

*Scissurella crispata* var. *paucicostata* JEFFREYS, 1865 (1862-1869), vol. 3, p. 284. - ODHNER, 1912, p. 13 [under var. *aspera* PHIL.].

*Scissurella* (*Schizotrochus*) *kelseyi* DALL, 1905, p. 124.

*Scissurella kelseyi* DALL. - DALL, 1921, p. 183. - OLDROYD, 1927, p. 830. - KEEF, 1935, p. 139; fig. 105. - KEEN, 1937, p. 45. - BURCH, 1946, p. 23.

*Scissurella chiricova* DALL, 1919, p. 370. - 1921, p. 183. - OLDROYD, 1927, p. 830. - KEEN, 1937, p. 45. - BURCH, 1946, p. 23.

**Diagnosis:** Shell globose, delicate, translucent white, whorls 4 to 5. Selenizone at periphery, open about  $\frac{1}{8}$  the circumference; edges sharp, raised. Axial sculpture of fine raised lines, curved anteriorly above slit band, crossed by fine spiral lines of equal strength. Aperture rounded, oblique, peritreme nearly complete, outer lip thin, inner lip slightly reflected; umbilicus deep. Operculum multi-spiral, thin.

**Dimensions:** Holotype, *Scissurella kelseyi*, alt. 6.0, diam. 5.5 mm; holotype, *S. chiricova*, alt. 2.5, diam. 3.0 mm.

**Type Material:** Type, *Scissurella crispata* FLEMING, not located. Type locality: Noss Island, Shetland Islands, Scotland. Types of nominal forms regarded as synonyms: *S. aspera* PHILIPPI, not located; *S. angulata* LOVÉN, not located; 4 syntypes, *Anatomus japonicus* A. ADAMS, BMNH (M. KEEN, Plate 56, Figures 3, 4); *Scissurella crispata* var. *paucicostata* JEFFREYS, not located; holotype *S. kelseyi* DALL, USNM 181820 (unfigured, missing from vial, presumed lost), USFC sta. 4353, off Pt. Loma, San Diego County, California, 640 fms.; holotype, *S. chiricova* DALL, USNM 206509 (Plate 56, Figure 2), USFC sta. 3340, SE of Chirikof Island, Alaska, 695 fms.

**Distribution:** North Atlantic: Spitzbergen, south to the Mediterranean, Morocco, Azores; New England, West Indies (ODHNER, 1912). Western Pacific: Japan, south to 33° N on Pacific coast (*S. japonica*, KURODA & HABE, 1952). Eastern Pacific: Chirikof Island, Alaska (56° N, 156° W), south to Cedros Island, Baja California (28° N). Eastern Pacific records: off Queen Charlotte Island, British Columbia, USFC sta. 2860, 876 fms. (USNM 206690); SW of Cape Cook, Vancouver Island, British Columbia, 1110 fms. (Cowan Coll., 5649); off La Jolla, San Diego County, California, 100 fms. (Berry Coll., 3215); off North Coronado Island, Baja California, USFC sta. 4382, 656 fms. (USNM 208901, Plate 56, Figure 1); 30 miles off Cedros Island, Baja California, 500 fms. (Stanford Univ. Coll.). In addition, there are 3 lots from the San Diego area in the U. S. National Museum, taken in depths ranging from 565 to 822 fathoms.

Depth records of *Scissurella crispata* in the eastern Pacific range from 100 to 1100 fathoms. In southern California it is evidently not uncommon in depths of 500 to 800 fathoms, judging from its occurrence at the few stations made at these depths. ODHNER (1912) reported

it as occurring in depths of 10 to 1000 fathoms in the North Atlantic and CLARKE (1962) included it as an abyssal species with a depth record of 1215 fathoms. HABE (1964) reported a depth of 50 to 150 meters for *S. japonica*, regarded here as a synonym.

**Remarks:** An account of the living animal of *Scissurella crispata* was given by FRETTER & GRAHAM (1962).

The radula of *Scissurella crispata* was figured by SARS (1878), copied by PILSBRY (1890). The illustration shows fine cusps on the rachidian and inner lateral teeth, while the outer, or fifth, lateral points outward and has fine cusps on the inner margin. The finely cusped marginals are numerous.

In both the North Atlantic and North Pacific the species shows variation in shell height. The more depressed form has received the name *Scissurella angulata* LOVÉN in the North Atlantic and *S. chiricova* DALL in the North Pacific. ODHNER (1912) figured a series of specimens of *S. crispata* from the North Atlantic to show the variation in height.

Although *Scissurella crispata* has heretofore been recorded only from the North Atlantic, the nominal west American forms *S. kelseyi* DALL and *S. chiricova* DALL show no distinguishing characteristics, seem to exhibit the same ranges of variation, and are known from comparable depths. I find no differences whatever between specimens of *S. crispata* collected off Sambo Reef, Florida (USNM 449410), and a specimen from off La Jolla (SSB 3215), and therefore consider the populations of both oceans to be conspecific. Illustrations of *S. japonica* ADAMS given by Japanese authors apply equally well to eastern Pacific and North Atlantic specimens, suggesting that a single boreal species is involved, not unexpected in a species having a bathymetric distribution that includes abyssal depths.

*Scissurella crispata* is similar in proportion to *S. lamellata* but lacks the pronounced axial ribbing of the latter species.

*Scissurella (Anatoma) lamellata* (A. ADAMS, 1862)

(Plate 56, Figure 8)

*Anatomus lamellatus* A. ADAMS, 1862, p. 347. — PILSBRY, 1890 (1888-1898), vol. 12, p. 59.

*Schizotrochus lamellatus* (A. ADAMS), — HABE, 1951, p. 66; plt. 11, figs. 7, 8.

*Scissurella lamellata* (A. ADAMS). — KURODA & HABE, 1952, p. 84. "*Scissurella kelseyi* DALL." — TALMADGE, 1966, p. 83.

**Diagnosis:** Shell minute, translucent white, whorls 4. Selenizone at periphery, edges sharply raised, open  $\frac{1}{8}$  the circumference of the last whorl. Sculpture of fine spiral

lines and prominent, broadly spaced axial ridges. Aperture rounded, oblique, peritreme nearly complete, outer lip thin, inner lip slightly reflected; umbilicus deep.

**Dimensions:** Alt. 3.8, diam. 3.6 mm (HABE, 1961); alt. 1.8, diam. 2.2 mm (Baxter Coll.).

**Type Material:** Type, *Anatomus lamellatus* A. ADAMS, not located (probably BMNH). Type locality: "Mino-Sima, 63 fm.; Gotto, 71 fm.; O-Sima [Japan]" (ADAMS, 1862).

**Distribution:** Pacific Coast of Japan south to 33° N (KURODA & HABE, 1952), to Prince William Sound, Alaska (60° N, 147° W). Eastern Pacific records: Port Dick, Kenai Peninsula, Alaska, dredged (LACM, ex Baxter; Plate 56; Figure 8); McLeod Bay, Montague Island, Prince William Sound, Alaska, 25 fms. (R. Talmadge coll.). The species is reported from the eastern Pacific here for the first time. Along with *Scissurella soyoeae* HABE, it has probably been overlooked because of its minute size.

Alaskan specimens of *Scissurella lamellata* have been dredged on fine sand bottoms at moderate depths in association with *S. soyoeae*. HABE (1951) reported the species at 224 and 283 meters depth off the island of Honshu, Japan.

**Remarks:** *Scissurella lamellata* resembles *S. crispata* but differs in having pronounced axial sculpture rather than the fine even reticulate sculpture of the latter.

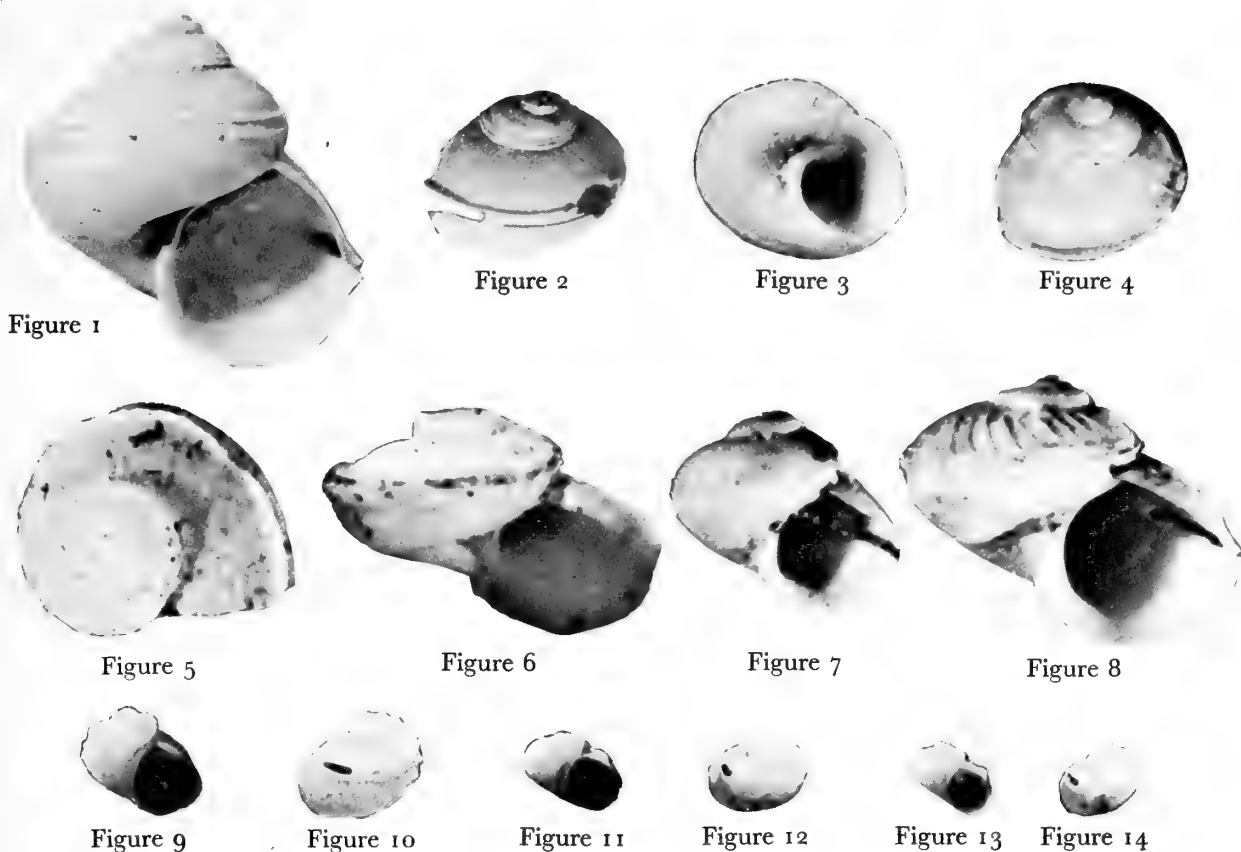
As is the case with *Scissurella soyoeae*, Alaskan specimens of *S. lamellata* are smaller than the Japanese specimen figured by HABE. In addition, the shell figured by HABE has a height greater than its diameter, rather than the contrary as indicated for the largest of the Alaskan specimens. However, HABE's illustration shows that the early whorls are more rapidly expanding than later whorls, suggesting that an additional whorl on the Alaskan specimens would produce a shell having similar dimensions. In features other than size, the Alaskan specimens agree with the illustrations of HABE.

*Scissurella (Anatoma) lyra* BERRY, 1947

(Plate 56, Figures 5, 6)

*Scissurella lyra* BERRY, 1947, p. 14; plt. 1, figs. 10, 11.

**Diagnosis:** Shell minute, translucent white, depressed, fragile; whorls  $3\frac{1}{2}$ , flattened above. Selenizone slightly above periphery, edges sharply raised, open  $\frac{1}{8}$  the circumference of last whorl. Axial sculpture of fine raised lines, curved anteriorly above slit band; spiral sculpture obsolete on apical surface, axial sculpture stronger than spiral sculpture on basal surface. Base moderately keeled; peri-



Figures 1 to 4: *Scissurella (Anatoma) crispata* FLEMING, x 8

1. Off North Coronado Island, Baja California, USFC sta. 4382, 656 fms; USNM 208901. Alt. 5 mm.
2. Holotype, *Scissurella chiricova* DALL. Southeast of Chirikof Island, Alaska, USFC sta. 3340, 695 fms. USNM 206509. Alt. 2.5 mm.

3, 4. Syntypes, *Anatomus japonicus* A. ADAMS. BM(NH):

Figures 5, 6: *Scissurella (Anatoma) lyra* BERRY, x 25

Off Southeast Farallon Island, California. 45 feet. LACM. Alt. 1.0 mm.

Figure 7: *Scissurella (Anatoma) soyoae* (HABE), x 25

Off Port Dick, Kenai Peninsula, Alaska, 20 fm. LACM. Alt. 1.1 mm.

Figure 8: *Scissurella (Anatoma) lamellata* (A. ADAMS) x 25

Off Port Dick, Kenai Peninsula, Alaska, 20 fm, LACM. Alt. 1.6 mm

Figures 9 to 14: *Sinezona rimuloides* (CARPENTER), x 15

9, 10: Carmel Submarine Canyon, Monterey County, California, 80 feet. LACM. Alt. 1.0 mm.

11, 12: Punta Colorado, Guaymas, Sonora, Mexico. LACM. Alt. 0.75 mm.

13, 14: Iquique, Chile, LACM. Alt. 0.7 mm.



treme complete, pillar broadly flaring at base; umbilicus deep.

**Dimensions:** Holotype, alt. 1.0, diam. 1.4 mm; Recent specimen, alt. 1.0, diam. 1.5 mm (LACM).

**Type Material:** Holotype, *Scissurella lyra* BERRY, Berry Coll., 12000, paratypes 12009; 2 paratypes, Stanford Type Coll. 7869. Type locality: Lower Pleistocene (Lomita formation), near 2<sup>nd</sup> and Pacific Streets, San Pedro, Los Angeles County, California.

**Distribution:** Lower Pleistocene: Lomita formation, San Pedro; Santa Barbara formation, Bath-house Cliff, Santa Barbara, California (BERRY, 1947). Recent: off Southeast Farallon Island, California, 45 feet (1 specimen, LACM ex McLean, Plate 56; Figures 5, 6); Carmel Submarine Canyon, Monterey County, California, 100 feet (McLean, 2 specimens). Recent specimens of *Scissurella lyra* have been collected on gravel bottoms near rock in steeply sloping sublittoral depths of 40 to 100 feet. At present there are but 3 Recent specimens known, despite continued efforts to collect specimens from fine siftings, using flotation techniques for recovering foraminifera. Further collecting should considerably extend the range in California.

**Remarks:** *Scissurella lyra* may be an analogue of the North Atlantic species, *S. umbilicata* JEFFREYS, 1883 (PILSBRY, 1890, vol. 12, p. 52; pl. 51, figs. 31, 32), which is also lenticular in shape. According to PILSBRY, *S. umbilicata* is "devoid of sculpture," however. *Scissurella lyra* is smaller and less elevated than the depressed forms of *S. crispata*.

*Scissurella (Anatoma) soyoae* (HABE, 1951)

(Plate 56, Figure 7)

*Schizotrochus soyoae* HABE, 1951, p. 66; pl. 11, figs. 3, 4.

"*Scissurella chiricova* DALL." — TALMADGE, 1966, p. 83.

**Diagnosis:** Shell minute, yellowish, whorls 4, rapidly expanding, rounded at the periphery. Selenizone at periphery, edges not sharply raised, open  $\frac{1}{8}$  of the circumference of the last whorl. Sculpture of fine axial and spiral lines. Peritreme complete, pillar reflected over deep umbilicus.

**Dimensions:** Holotype, alt. 2.3, diam. 2.8 mm; Alaskan specimen, alt. 1.3, diam. 1.6 mm (Talmadge coll.).

**Type Material:** Holotype, *Schizotrochus soyoae* HABE, National Science Museum, Tokyo, Japan. Type locality: "Off Tsugaru Peninsula, Northern Honshu (Soyo-maru Station no. 647, 86 m. in depth)."

**Distribution:** Northern Honshu, Japan (140° E, 41° N), to Prince William Sound, Alaska (60° N, 147° W).

Eastern Pacific records: Port Dick, Kenai Peninsula, Alaska, 20 fms. (LACM, ex Baxter, Plate 56; Figure 7); McLeod Bay, Montague Island, Prince William Sound, Alaska, 25 fms. (Talmadge coll.). It occurs on bottoms of fine sandy mud. Further collecting in Alaska should considerably extend the range of this species, which has undoubtedly been overlooked, owing to its minute size.

**Remarks:** *Scissurella soyoae* has the turbinate outline of *S. crispata*, but differs in its smaller size, distinct yellow coloration, and absence of raised edges around the selenizone.

Specimens in the Talmadge and Baxter collections are smaller than the type specimen described by HABE, but the number of whorls is correspondingly less. They fit the description of *Scissurella soyoae* in every respect, including the yellowish cast of the shell.

#### *Sinezona* FINLAY, 1927

*Sinezona* FINLAY, 1927, p. 341. Type species, *Scissurella brevis* HEDLEY, 1904. Recent, New Zealand. Synonym, *Schismope* Auctt., non JEFFREYS.

*Coronadoa* BARTSCH, 1946, p. 281. Type species by OD, *C. simonsae* BARTSCH, 1946.

**Diagnosis:** Shell minute, white, turbinate, sculptured with axial folds and spiral striae. Foramen elongate, positioned in outer lip on final whorl, closed at lip margin; slitband with slightly raised edges; umbilicus deep.

*Sinezona* differs from *Scissurella* in having the slitband closed at the lip margin, fewer whorls, and a broader umbilical chink.

*Sinezona rimuloides* (CARPENTER) is the only species known in the west American fauna. DALL (1919) described the species "*Schismope*" *caliana*, but the foramen in the type specimen is clearly an accidentally acquired hole, removing the species from consideration in the family Scissurellidae.

*Coronadoa* BARTSCH, 1946, was based on immature specimens of *Sinezona rimuloides*, collected prior to development of the foramen. The slitband and foramen in this species does not appear until the shell reaches a height of 0.5 mm, which is the maximum dimension given by BARTSCH for *Coronadoa*. The early axial sculpture of *Coronadoa* is identical with that of *Sinezona rimuloides*, the shell is white, and the operculum is corneous and multispiral. BARTSCH felt that his genus *Coronadoa* should be placed in the superfamily Trochacea because of the rhipidoglossate radula. However, his radular illustration serves to place it in the family Scissurellidae, for it shows an enlarged outermost lateral tooth with fine cusps, a feature characteristic of the family (THIELE, 1929, p. 30).

*Sinezona rimuloides* (CARPENTER, 1865)

(Plate 56, Figures 9 to 14)

- Scissurella rimuloides* CARPENTER, 1864, p. 548 [nomen nudum]. – 1865, p. 271 [described]. – PILSBRY, 1890 (1888 - 1898), vol. 12, p. 68 [copy Cpr.]. – PALMER, 1951, p. 73; plt. 1, figs. 20 - 22 [Cpr. drawing of holotype]. – BRANN, 1966, p. 47; plt. 22, fig. 698 [Cpr. drawing].
- Schismope rimuloides* (Cpr.). – PILSBRY, 1903, p. 84. – DALL, 1921, p. 183. – OLDROYD, 1927, p. 831. – KEEN, 1937, p. 45. – BURCH, 1946 (1944 - 1946), no. 58, p. 23.
- "*Schismope coronata* (WATSON)". – DALL, 1921, p. 183 [not *Scissurella coronata* WATSON, 1886].
- "*Schismope californica* BARTSCH." – DALL, 1923, p. 4 [nomen nudum, intended for *S. coronata* WATSON of DALL, 1921]. – KEEN, 1937, p. 45 [as "*S. californica* DALL," nomen nudum]. – BURCH, 1946, p. 23 [nomen nudum].
- Coronadoa simonsae* BARTSCH, 1946, p. 281, figs. 1 [radula], 2 [operculum], 3 [shell].

**Diagnosis:** Shell minute, white, whorls 3, rapidly enlarging, suture distinct. Slitband on final whorl, edges raised; foramen elongate, close to shell margin. Axial sculpture of raised ridges, becoming obsolete on final whorl; spiral lirae on base of final whorl. Aperture oblique, peritreme complete, umbilical chink broad.

**Dimensions:** Average sized specimen, alt. 0.8, diam. 0.6 mm; holotype, *Coronadoa simonsae* BARTSCH, alt. 0.5, diam. 0.6 mm (BARTSCH, 1946).

**Type Material:** Holotype, *Scissurella rimuloides* CARPENTER, BMNH, Mazatlan coll., slide no. 1532 (M. Keen, personal communication). Type locality: Mazatlan, Sinaloa, Mexico. Type of nominal form regarded as synonym: lectotype (here designated), *Coronadoa simonsae* BARTSCH, USNM 346654; 2 paratypes, USNM 346655 (other original specimens believed lost), North Coronado Island, Baja California.

**Distribution:** Farallon Islands, California (36° N), to Mazatlan, Mexico (23° N). Iquique, Chile (20° S). Records: Southeast Farallon Island, 45 feet (McLean); Carmel Submarine Canyon, Monterey County, California, 80 feet (LACM ex McLean, Plate 56; Figures 9, 10); Middle Coronado Island, Baja California, 40 feet (LA CM); Punta Colorado, Guaymas, Sonora, Mexico (LA CM, ex Berry, Plate 56; Figures 11, 12); Iquique, Chile (LACM, ex L. Marincovich, Plate 56; Figures 13, 14). The specimens from Chile are indistinguishable from northern specimens. Although the species has been recognized in the Panamic province only from Guaymas and Mazatlan, it probably occurs throughout this faunal area since it is also present in the south temperate Peruvian province. The distribution of *Sinezona rimuloides* thus encompasses 4 faunal provinces: the Oregonian, Californian, Panamic, and Peruvian provinces.

*Sinezona rimuloides* is evidently not uncommon throughout its range. In California I have found it in the intertidal zone and in the sublittoral under-kelp zone at nearly all localities at which bottom samples have been collected. It is most easily recovered by flotation of the finely screened dry samples in heavy liquids.

**Remarks:** A radular description for *Sinezona rimuloides* may be taken from that given by BARTSCH for *Coronadoa simonsae* (the juvenile of *S. rimuloides*): "The radula has a 5-cusped rachidian tooth followed by three tricuspid laterals and a 9-cusped major lateral, which is succeeded by 14 4-cusped marginals." The outermost lateral of *Sinezona rimuloides* is not pointed as in *Scissurella crispata*. Laterals total 4, rather than the 5 indicated by THIELE (1929) in his diagnosis of the family.

Specimens of *Sinezona rimuloides* from the same locality often exhibit considerable variation in sculpture. Some specimens show little indication of the axial ribs; in some they become obsolete on the final whorl, while in other specimens they persist on the final whorl. The spiral sculpture on the base may be pronounced or nearly lacking. Position and size of the foramen are highly variable. The foramen is usually elongate but may be shortened, and in rare examples the slit is open to the edge of the lip.

*Sinezona rimuloides*, described from Mazatlan, had not been known in the Californian fauna until reported by PILSBRY (1903). DALL (1921) listed "*Schismope*" *rimuloides* and "*S.*" *coronata* WATSON. Later, DALL (1923) replaced "*S.*" *coronata* as follows: "Bartsch regards this as a new species which he calls *S. californica*." This introduction of the name *S. californica* made it a *nomen nudum* and the species has not since been validly described under the name, although it has come into use for the Californian form in faunal listings. However, Californian specimens differ in no way from specimens of *Sinezona rimuloides* from Guaymas, Mexico, in the Panamic province. I have not seen specimens from Mazatlan, but Carpenter's own drawings of the holotype (PALMER, 1951; BRANN, 1966) clearly indicate the same species. Disposition of *Coronadoa simonsae* has been discussed under the generic heading.

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## The Holotype of the Abyssal Dorid Nudibranch

### *Bathydoris aoica* MARCUS & MARCUS, 1962

BY

JAMES R. LANCE

ON FEBRUARY 15, 1960, Mr. Robert Parker of the Scripps Institution of Oceanography, La Jolla, California, dredged the first specimen of the abyssal genus *Bathydoris* so far reported from the eastern Pacific area. The animal was captured in a 30 foot otter trawl northeast of Isla Guadalupe, Baja California, Mexico, at about 1500 fathoms. It was sent to Professor Ernst Marcus of the University of São Paulo, Brasil, who later published an anatomical account and reviewed the genus (MARCUS & MARCUS, 1962) and indicated that "The specimen has been returned to the Scripps Institution of Oceanography." A

subsequent search of institutional collections failed to reveal any trace of the animal.

The specimen has recently been found and given to the California Academy of Sciences, Department of Invertebrate Zoology, where it is registered as CAS No. 306 in the type collection. The holotype consists of the entire animal (partially dissected) plus a separate vial containing contents of the alimentary tract.

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*Perplicaria clarki* MAXWELL SMITH, A Living Fossil

BY

AXEL A. OLSSON

AND

EUGENE BERGERON

(Plate 57)

WHILE MONOGRAPHING the rich molluscan fauna of the Caloosahatchee of Florida, DALL in 1890 came across a singular shell, so perplexing that he named it "*Perplicaria perplexa*" assigning it with some hesitation to the Mitridae. This curious shell has remained one of the most interesting members of the Caloosahatchee fauna, rare at most localities, but sufficient numbers have been gathered over the years that it is now well represented in many museum and private collections and its familial relationship understood. Druid Wilson was the first to indicate its proper placement amongst the Cancellariidae which its early growth forms clearly show. A full growth series of the species was illustrated by OLSSON & HARBISON (1953) in their monograph of the Pliocene mollusca from St. Petersburg, Florida. The earliest species of the genus is *P. prior* MAURY, 1910, from the Lower Miocene of the Chipola River in northern Florida, the species as yet known only from the type specimen. In 1928, WOODRING illustrated a small *Mitra*-like *Cancellaria* from the Bowden Miocene of Jamaica which may prove to be a *Perplicaria* when more fully known.

The next advance in our knowledge of *Perplicaria* came with the unexpected discovery of a living species at Panama through the description of *P. clarki* by MAXWELL SMITH in 1947 based on a small specimen collected by Mr. Walter D. Clark (a former postmaster) at Venado Beach near the Pacific terminus of the Panama Canal. The specimen is a small, immature shell, about 16.2 mm in length and was so poorly described and illustrated that its characters remained obscure. A second specimen of this rare species was collected recently by the junior author (Bergeron) at Isla Senorita (a small patch of rocks near the island of Pedro Gonzalez) in the Pearl Islands of the Gulf of Panama. This specimen has a length 32.6 mm, about twice the size of Maxwell Smith's type. Although dead when found and somewhat faded in color, it is otherwise perfect. Its most outstanding feature is

the series of thickened swellings or varices along the length of the spire marking former lip positions. Its color is a pale brown or fawn encircled by a series of small, elongated, white spots. Two small pillar plaits are visible in the aperture about the middle of the inner lip.

The resemblance of *Perplicaria clarki* to the fossil *P. perplexa* is striking, especially as to shape, the principal differences being its strong varices which are very slightly developed in the fossil, its somewhat lesser inflation of the early spire whorls and a smoother overall sculpture. *Perplicaria perplexa* is a variable species, hence these differences are not particularly significant.

Our illustrations of *Perplicaria clarki* show the shell in various aspects. Figure 1 (Plate 57) shows the general color pattern of encircling white spots; the other two figures show the shell after being whitened with magnesium oxide to bring out details of sculpture.

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## Northern and Southern Range Extensions of *Aplysia vaccaria*

(Gastropoda : Opisthobranchia)

BY

JAMES R. LANCE

THE GIANT BLACK SEA HARE *Aplysia vaccaria* WINKLER, 1954, although locally common, has been reported from a very narrow range extending from San Pedro, California, to the vicinity of Cabo Colnett on the Pacific side of the Baja California Peninsula (FARMER, 1967). The fact that this enormous gastropod has not been indicated from additional localities is perplexing since it is possibly the world's largest, and consequently one of the most conspicuous, of all intertidal invertebrates. Individuals measuring 15 inches in length are not uncommon at Laguna Beach, Doheny Beach, La Jolla and Point Loma (California) at least during the winter and early spring. Subtidal specimens from off La Jolla have been reported to attain a length of up to 30 inches (WINKLER & DAWSON, 1963).

During a field trip to the rocky intertidal area at Hammond's Point, Santa Barbara, on November 12, 1966, I observed about 20 individuals of this species interspersed among an equal number of the smaller and lighter colored *Aplysia californica* COOPER, 1863. Mr. Gale Sphon, of the Santa Barbara Museum of Natural History, informs me that *A. vaccaria* is quite common on the mud flats in Morro Bay. These observations extend the range about 200 miles to the northwest. It is likely that Morro Bay and its environs will prove to be the northern limit of *A. vaccaria* since it is unknown from the Monterey peninsula and regions to the north, where collecting is rather intense.

On April 12 and May 14, 1964, Miss Joan E. Steinberg and I observed *Aplysia vaccaria* to be an abundant inhabitant of the rocky intertidal regions at Bahía de los Angeles

in the northern part of the Gulf of California. Fewer numbers of *A. californica* were also observed in the same habitat. This latter species has already been reported from several Gulf localities (WINKLER, 1958).

The present records add another species to the list of opisthobranchs indigenous to both the Californian and the northernmost regions of the subtropical Panamic faunal provinces summarized in an earlier paper (LANCE, 1966).

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Figure 1

Figure 2

Figure 3

*Perplicaria clarki* MAXWELL SMITH, 1947

Figure 1: General Color Pattern of Encircling White Spots.

Figures 2 and 3: Shell whitened with Magnesium Oxide  
to bring out Details of Sculpture.



# A Checklist of Mollusks for Guaymas, Sonora, Mexico

BY

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(1 Map)

## INTRODUCTION

GUAYMAS, ON THE EAST SHORE of the Gulf of California, at Latitude 28° 00' N, Longitude 111° 00' W is on the Mexican West Coast Highway 15, 260 miles south of the International Boundary at Nogales. Because of its geographical location and because of the variety of habitats available, this area permits a major sampling of the molluscan life of the Gulf. The diversified coastal terrain consists of numerous rocky promontories, between which lie long sandy beaches, bays, and quiet esteros. The mollusks here include: *Chione*, *Pitar*, *Oliva*, and *Terebra* on the sandy beaches; *Mitra*, *Typhis*, *Ocenebra*, and *Nuculana* in the bays; *Crassispira*, *Epitonium*, *Thais*, *Conus*, *Pecten*, and *Fusinus* in the esteros. The rubble at the foot of promontories provides habitat for *Neosimnia*, *Cypraea*, *Pterynotus*, and *Semele*.

This paper is intended to provide collectors with a working list and does not presume to be all-inclusive. The specimens enumerated include those taken by active collectors in an area of about fifteen miles west and ten miles east of the city of Guaymas. Specimens taken by dredging, diving and shore collecting are listed. When very few specimens of a species are recorded it is sometimes difficult to know whether the specimens have been introduced by shrimp boats or are rare native inhabitants.

The map, drawn by Roy Poorman, shows the number and extent of the collecting areas. To help the reader orient himself certain key points are named.

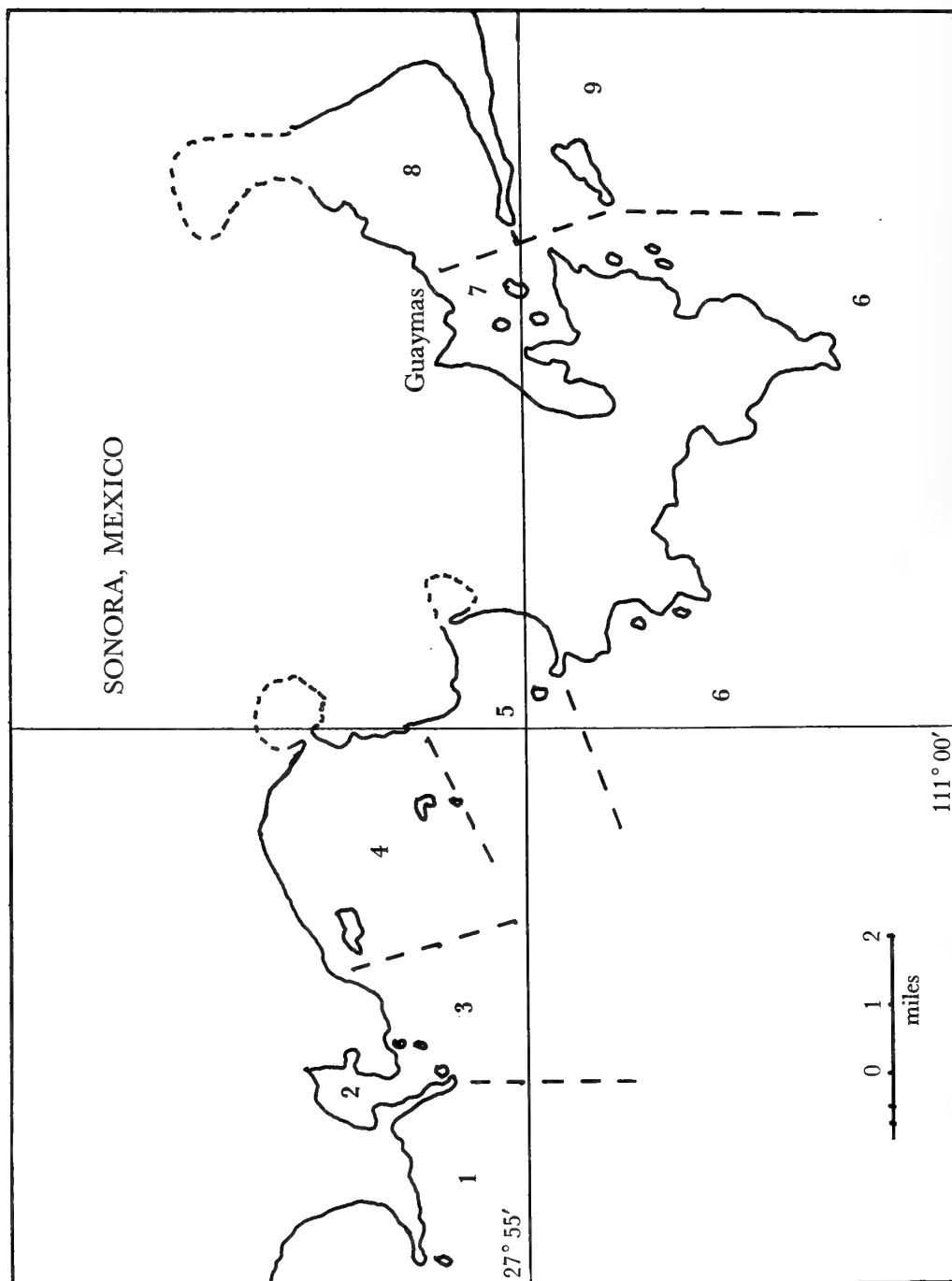
## ECOLOGICAL NOTES ON THE COLLECTING AREAS

(see Map)

**Area 1:** In this area are several sandy beaches and rocky coves which can be reached by foot. The sand beaches are rewarding only at extreme low tide when *Oliva*, *Strombus*, and *Chione* can be taken. The rocky coves yield *Cypraea*, Turridae, and several of the Mitridae under small rocks and in crevices. Diving along the edge of the massive rock-falls, in 7 to 20 m of water, provides good hunting. From just beyond the larger rocks and sloping away from shore is a region of rocky rubble decreasing in size with the distance from shore. This region is from 12 to 17 fathoms in depth and about 300 feet wide. Starting near shore and dredging away from the cliffs brings many rarities such as *Typhis lowei*, *Clathrodrillia dichroa*, *Mitra sphoni*, and *Semele jovis*. Beyond the sloping shelf a silty bottom extends out to 30 fathoms at about one mile from shore. This area produces *Clavus*, *Cancellaria*, *Mangelia*, *Lucina*, *Cuspidaria*, and *Papyridea*.

**Area 2:** The upper end of the bay is a mangrove swamp which gives way to large expanses of sand flats at low tide. The drainage channels and the mangrove roots yield *Modulus*, *Cerithium*, and *Nassarius*. The sand area hosts *Turritella*, *Chione*, *Fusinus*, and *Conus*. As one proceeds down the sides of the estero toward the mouth, the sand gives way to turnable rocks where *Crassispira*, *Epitonium*, *Anachis*, *Cypraea*, and *Lima* are taken. In the channel, corals and gorgonians and the respective predators which feed on them may be found. Dredging is not practical

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because the bottom is coarse, unproductive gravel which clogs the dredge with dead weight.

**Area 3:** There are two headlands in this area which provide fine diving. The rest of the area must be dredged because the depth ranges from 15 to 30 fathoms. The bottom varies from rocky bars to sand and fine silty mud. *Ocenebra perita*, *Niso splendidula*, *Pterynotus pinniger*, and *Crassispira excentrica* have been taken.

**Area 4:** This area includes Estero Soldado whose shoreline is bounded by mangroves. At low tide *Thais kiosquiformis*, *Neosimnia*, and *Cassia centiquadrata* may be taken. The offshore area is dotted with several small islands. Around these one may dredge *Semele junonia*, *Clathrodrillia dichroa*, *Typhis grandis*, and *Corbula speciosa* in about 12 fathoms.

**Area 5:** Bacochibampo Bay has a rocky coastline on the north and south. This provides good areas for skindiving where *Terebra*, *Neosimnia*, and *Cypraea* have been taken. A long sand beach forms the head of the bay on the east. Collecting is not very rewarding here but *Muricanthus nigratus* has been taken on the beach recently. Punta Colorado forms the south shore of the bay. Medium-size rocks covered with much plant growth abound here. On this vegetation are found *Trivia solandri*, *Jenneria pustulata*, *Cypraea*, and *Calliostoma*. *Neosimnia* and *Cyphoma* may be taken on the gorgonians at the far point on a very low tide.

**Area 6:** The shore is rock-strewn and difficult to reach except over a dirt road leading from behind the Cortez Hotel two miles to Saladita Bay. On shore may be taken *Mitra tristis* and *Ocenebra parva*. Diving one may collect at from 10 to 30 feet *Cerithium uncinatum* and *Cypraea isabellamexicana*. As the shoreline leads southwest toward Cabo Haro the cliffs become more precipitous, making shore collecting more difficult. Off shore, the water becomes deeper, necessitating heavier dredging equipment.

**Area 7:** The inner harbor of Guaymas is a busy port but at high tide the sea fills brackish ponds where mangroves grow. At the roots of *Salicornia* plants are *Melampus*. The south shore of the harbor is rocky and provides habitats for numerous *Muricopsis*, *Crepidula*, and *Acmaea*.

**Area 8:** This is a back bay area composed mainly of mud flats. The northwest side is a rubble-strewn beach where *Cymatium gibbosum* and *Calliostoma leanum* may be taken. *Semele flavescens* may be dug from the rubble while *Chione fluctifraga* is in the mud. A long sand bar is exposed at extreme low tide where *Tegula rubroflammulata* may be found hidden inside dead valves of the larger clams.

**Area 9:** Playa Cachorit is a long sand beach which fronts directly on the Gulf. This is an area for *Turritella*, *Chione*,

*Pitar*, while *Petricola parallela* and *Pholas chiloensis* may be dug from the hard mud reefs exposed at low tides. Rare deep water forms have been taken by people who have walked along this beach after a storm.

## ACKNOWLEDGMENTS

Major contributions toward the preparation of this checklist were made by a number of people. Our special thanks go to Dr. Myra Keen for her help in the exacting task of reading the manuscript and for her many constructive suggestions. To Dr. James McLean, of the Los Angeles Museum of Natural History, we are indebted for time given to consultation during the preparation of the manuscript. We owe thanks to Dr. S. Stillman Berry, Dr. Homer King, Dr. James McLean, Mr. Gale Sphon and the Santa Barbara Museum of Natural History for making their respective collections available to us.

A special word of appreciation is due to Dr. S. Stillman Berry who not only offered his own extensive collection for inclusion in the list, but also gave many hours to checking and verifying the identification of doubtful specimens.

## SYSTEMATIC ACCOUNT

In this list the following format is adopted:

1. The species number given in KEEN (1958) and the scientific name. Species listed without a number are not included in that reference.
2. Range extensions marked with an asterisk preceding the name of the species; the most northerly previously recorded place of occurrence, according to KEEN (*op. cit.*) is listed.
3. The habitat of the specimen(s) is given, such as: "sand beach", "intertidally, under rocks", or "sand and broken shell bottom".
4. Relative abundance or rarity is indicated by the terms "common", "uncommon", or "rare". It should be remembered that these terms are subject to the conditions under which each collector finds his specimens.
5. The following individuals have made their collections available and are designated in the list by initials:

Dr. S. Stillman Berry	B
Helen and Joseph DuShane	D
Dr. Homer King	K
Dr. James H. McLean	M
Forrest and Roy Poorman	P
Santa Barbara Museum of Natural History	SBM
Gale Sphon	S

## PELECYPODA

- 1 *Nucula declivis* HINDS, 1843. Rare (3, 6, 9), dredged 15-17 fathoms rock and shell bottom; diving 10 m; beach (B, M, P).
- 2 *Nucula exigua* SOWERBY, 1833. Rare (3), dredged 17 fathoms on rock and broken shell bottom (P).
- 5 *Nuculana costellata* (SOWERBY, 1833). Common (3, 4, 5, 6), dredged 10-100 fathoms broken shell and rock bottom (D, P, S).
- 6 *Nuculana marella* HERTLEIN, HANNA & STRONG, 1940. Rare (6), dredged 45-100 fathoms on broken shell bottom (B).
- 9\* *Nuculana eburnea* (SOWERBY, 1833). Rare (6), dredged 15-25 fathoms on broken shell and rock bottom; El Salvador (D).
- 10 *Nuculana elenensis* (SOWERBY, 1833). Common (3, 5, 6), dredged 10-100 fathoms on broken shell and rock bottom (D, SBM, S).
- 11\* *Nuculana fastigata* KEEN, 1958. Uncommon (6), dredged 15-25 fathoms on broken shell and rock bottom; Acapulco (D, S).
- 12 *Nuculana impar* (PILSBRY & LOWE, 1932). Common (3, 6), dredged 15-40 fathoms on broken shell and rock bottom (B, D, K, P).
- 13 *Nuculana laeviradius* (PILSBRY & LOWE, 1932). Common (3, 4, 6), dredged 10-25 fathoms on broken shell and rock bottom (D, P, S).
- 16\* *Nuculana acrita* (DALL, 1908). Rare (3, 4), dredged 15-17 fathoms on rock and shell bottom; Panama (P).
- 20\* *Nuculana hindsii* (HANLEY, 1860). Rare (3), dredged 15 fathoms; Costa Rica (B).
- 26 *Adrana exoptata* (PILSBRY & LOWE, 1932). Rare (7), dredged (B).
- 27 *Adrana penascoensis* (LOWE, 1935). Uncommon (3, 4), dredged 10-15 fathoms in silty mud (P).
- 36 *Arca mutabilis* (SOWERBY, 1833). Uncommon (4), inlet to estero, Bacochibampo Bay (B, P).
- 37 *Arca pacifica* (SOWERBY, 1833). Uncommon (3, 4, 6), dredged 20 fathoms on broken rock bottom (B, P, SBM).
- 39 *Barbatia bailyi* (BARTSCH, 1931). Common (2), intertidal around rocks (P).
- 40 *Barbatia gradata* (BRODERIP & SOWERBY, 1829). Uncommon (2), intertidal around rocks; diving at 3-7 meters (M, P).
- 41 *Barbatia rostrae* BERRY, 1954. Common (2, 6), intertidal under rocks (P, SBM).
- 43 *Barbatia reeveana* (ORBIGNY, 1846). Intertidal under rocks (2), (B, P).
- 44 *Barbatia illota* (SOWERBY, 1833). Dredged 10 fathoms on broken shell and rock bottom; diving at 3-7 meters (4), (M, P).
- 46 *Arcopsis solida* (SOWERBY, 1833). Common (2, 3, 4, 6), dredged 17 fathoms on broken shell and rock bottom (B, D, M, P, SBM).
- 48 *Anadara mazatlanica* (HERTLEIN & STRONG, 1943). Dredged 20-40 fms. (6), (B).
- 55 *Anadara perlabiata* (GRANT & GALE, 1931). Common (4, 6), dredged 15-25 fms. and shore collected in estero (B, D).
- 56 *Anadara grandis* (BRODERIP & SOWERBY, 1829). Uncommon (2, 4), (P, SBM).
- 57 *Anadara multicostata* (SOWERBY, 1833). Common (1, 2, 3, 4, 5, 6), dredged 6-100 fms. varied bottoms; shore collected low tide, sand bars, quiet estero waters (D, K, M, P, S).
- 58 *Anadara aviculaeformis* (NYST, 1844). Rare (6), (S).
- 59 *Anadara biangulata* (SOWERBY, 1833). Uncommon (4), low tide, sand bars in estero (D).
- 60\* *Anadara cepoides* (REEVE, 1844). Rare (1, 3, 4, 6), dredged 10-25 fms. broken shell and rock bottom; Cerralvo Island (P, S).
- 61 *Anadara concinna* (SOWERBY, 1833). Dredged 15 to 100 fms. (6), (D, S).
- 65 *Anadara reinharti* (LOWE, 1935). Dredged 10-17 fms. rock and broken shell bottom (3, 4, 6), (D, P, S). *Anadara hyphalopilema* CAMPBELL, 1962. Dredged 40 fms. (6), type locality (B).
- 66 *Lunarca brevifrons* (SOWERBY, 1833). Uncommon (3), dredged 10 fms. on broken shell and rock bottom (P).
- 74 *Glycymeris gigantea* (REEVE, 1843). Valves dredged 10 fms. and beach valves (1, 9), (B, P).
- 75 *Glycymeris maculata* (BRODERIP, 1832). Common (1, 4, 5), dredged 10-15 fms. on broken shell and rock bottom (D, K, P, SBM).
- 76 *Glycymeris multicostata* (SOWERBY, 1833). Uncommon (3, 5, 6), dredged 17 fms. on broken shell and rock bottom; diving at 3-7 meters (D, K, M).
- 77\* *Glycymeris tessellata* (SOWERBY, 1833). Uncommon (1, 3, 4, 6), dredged 10-40 fms. broken shell and rock bottom; Manzanillo (K, P, S).
- 80 *Brachidontes multiformis* (CARPENTER, 1855). Common (4, 5, 6), intertidal around rocks (B, D, SBM).
- 83 *Hormomya adamsiana* (DUNKER, 1857). Intertidal on rocks (6, 7), (SBM).
- 84\* *Mytella falcata* (ORBIGNY, 1846). Intertidal among rocks (8); Petatlan Bay, Guerrero, Mexico (B).
- 85\* *Mytella guyanensis* (LAMARCK, 1819). Uncommon (2, 3, 4), dredged 17 fms. on rock bottom; southern



- Mexico (B, D, P, S).
- 87 *Septifer zeteki* HERTLEIN & STRONG, 1946. Dredged 17 fms. on broken shell and rock bottom; diving 3-7 meters (3, 6), (M, P).
- 88 *Crenella divaricata* (ORBIGNY, 1853). Rare (3), dredged 17 fms. on broken shell and rock bottom (D, P).
- 90 *Lithophaga aristata* (DILLWYN, 1817). Common (2, 6), dredged 5 fms. in coral base and in *Spondylus calcifer* (B, D, M, P, SBM).
- 92\* *Lithophaga calyculata* (CARPENTER, 1856). Intertidal in estero (2); southern Gulf of California (B).
- 95 *Lithophaga spatiosa* (CARPENTER, 1856). Dredged 10-15 fms. (5), (B, K).
- 99\* *Gregariella denticulata* (DALL, 1871). Rare (3), dredged 17 fms. on broken shell and rock bottom; Acapulco (P).
- 101 *Modiolus capax* (CONRAD, 1837). Common (2, 6), intertidal on rocks; dredged 100 fms. (D, M, P).
- 102\* *Modiolus eiseni* STRONG & HERTLEIN, 1937. Rare (5), dredged 10 fms. silty bottom; Outer Gorda Bank, Gulf of California (S).
- 104\* *Amygdalum americanum* SOOT-RYEN, 1955. Rare (5), dredged 15 fms. on silty mud; Tenacatita Bay (P).
- 106 *Lioberus salvadoricus* (HERTLEIN & STRONG, 1946). Uncommon (3, 4, 6), dredged 15 fms. sand and shell bottom (D, P).
- 107 *Pteria sterna* (GOULD, 1851). Uncommon (2, 4, 6), intertidal under rocks; dredged 15-25 fms. broken shell and rock bottom (B, D, M, P).
- 108 *Pinctada mazatlanica* (HANLEY, 1856). Uncommon (3, 6), intertidal on rocks (D, M, P, SBM).
- 111\* *Pinna rugosa* SOWERBY, 1835. Uncommon (2, 8), low tide among rocks and gravel; tip of Lower California (B, D, SBM).
- 113 *Atrina tuberculosa* (SOWERBY, 1835). In mud and silt (8), (B).
- 115 *Isognomon chemnitzianus* (ORBIGNY, 1853). Common (2, 4, 5, 6), intertidal attached to rocks (D, K, M, P, SBM).
- 117 *Ostrea angelica* ROCHEBRUNE, 1895. Common (2, 4), dredged 17 fms. on broken shell and rock bottom (D, M, P).
- 119 *Ostrea conchaphila* CARPENTER, 1857. Uncommon (6), intertidal attached to rocks (SBM).
- 120 *Ostrea corteziensis* HERTLEIN, 1951. Uncommon (4), (K).
- 123 *Ostrea megodon* HANLEY, 1846. Uncommon (3, 6), dredged 90-100 fms. broken shell bottom (B, D, K, P).
- 124 *Ostrea palmula* CARPENTER, 1857. Common (2, 4), in estero (B, S).
- 125\* *Pecten sericeus* HINDS, 1845. Uncommon (6), dredged 15-90 fms. rubble bottom; southern Gulf of California (B, D, K, S).
- 126 *Pecten vogdesi* ARNOLD, 1906. Common (3, 4, 5, 6), dredged 10-100 fms. on broken shell and rock bottom; in estero (B, D, K, M, P, S, SBM).
- 127\* *Aequipecten euterpes* (BERRY, 1957). Rare (6), dredged 50-100 fms. broken shell bottom; Acapulco, Mexico (D).
- 129 *Aequipecten tumbezensis* (ORBIGNY, 1846). Uncommon (5, 6), dredged 15-20 fms. (B, K).
- 130\* *Aequipecten velero* (HERTLEIN, 1935). Rare (4), dredged 15 fms. on broken shell and rock bottom; Mazatlan (P).
- 132 *Aequipecten circularis* (SOWERBY, 1835). Common (2, 3, 5, 6), dredged 7-100 fms. on broken shell and rock bottom; diving 3-7 meters; in esteros intertidally (B, D, K, M, P, S).
- 133 *Chlamys lowei* (HERTLEIN, 1935). Common (3, 4, 6), dredged 15-100 fms. broken shell and rock bottom (D, P, S).
- 135 *Cyclopecten pernomus* (HERTLEIN, 1935). Common (2, 3, 4, 5), dredged 7-17 fms. (D, K, P, SBM).
- 137 *Lyropecten subnodosus* (SOWERBY, 1835). Uncommon (3, 4), juveniles dredged 17 fms. broken shell and rock bottom; diving 3-7 meters (dead specimen); in estero (B, D, M, P).
- 140 *Lima tetrica* GOULD, 1851. Common (2, 3, 4, 6), dredged 15 fms. broken shell and rock bottom; under rocks and around and on mangrove roots; diving 3-7 meters (D, M, P, SBM).
- 142 *Lima orbigny* LAMY, 1930. Common (3, 4), dredged 15 fms. broken shell and rock bottom (P).
- 143 *Lima similaris* DALL, 1908. Rare (2, 3), dredged 15 fms. broken shell and rock bottom, valves only (D, P).
- 144 *Lima pacifica* ORBIGNY, 1846. Uncommon (2), under rocks, intertidally (D, M).
- 146 *Spondylus calcifer* CARPENTER, 1857. Common (1, 3, 5), attached to rocks, low tide; diving 3-7 meters (B, D, M, P).
- Spondylus ursipes* BERRY, 1959. Intertidal (3), (B).
- 147 *Plicatula anomioides* KEEN, 1958. Attached to rocks, low tide (5), type locality (B, D).
- 150 *Plicatula spondyloopsis* ROCHEBRUNE, 1895. Attached to rocks (4), (K).
- 151 *Anomia adamas* GRAY, 1850. Common (2, 7, 8), attached to rocks, low tide (B, D, M, P, SBM).
- 152 *Anomia peruviana* ORBIGNY, 1846. Common (5, 6),

- dredged 40 fms.; intertidal on rocks (D, K, S).
- 155 *Placunanomia cumingii* BRODERIP, 1832. Rare (3), dredged 17-40 fms. broken shell and rock bottom (B, P).
- 157 *Crassatella digueti* LAMY, 1917. Uncommon (3, 5, 6), dredged 17-25 fms. broken shell and rock bottom (D, M, P, S, SBM).
- 158 *Crassatella gibbosa* SOWERBY, 1832. Uncommon (2, 3, 5, 6), dredged 10-100 fms. broken shell and rock bottom (D, K, P, S, SBM).
- 159 *Crassinella pacifica* (C. B. ADAMS, 1852). Common (3, 4), dredged 15 fms. broken shell and rock bottom (D, P).
- 162 *Cardita affinis* SOWERBY, 1833. Common (2, 4, 6), intertidal under rocks (B, K, M, P, SBM).
- 163 *Cardita crassicostata* (SOWERBY, 1825). Rare (1, 3), dredged 10-17 fms. broken shell and rock bottom (P).
- 165 *Cardita laticostata* SOWERBY, 1833. Common (7, 8, 9), low tide in muddy sand (B, D, K, S).
- 166 *Cardita megastrophia* (GRAY, 1825). Uncommon (1, 3, 4, 6), dredged 10-25 fms. broken shell and rock bottom (B, P, S).  
*Galeomma mexicanum* BERRY, 1959. Rare (1), dredged 10 fms. rock and gravel bottom, valve only (P).
- Thyasira excavata* DALL, 1901. Rare (1), dredged 10 fms. gravel and silt bottom, valve only (P).
- 184 *Lucina cancellaris* PHILIPPI, 1846. Uncommon (3, 5, 6), dredged 15-100 fms. broken shell and rock bottom (D, K, P, S).
- 187 *Lucina prolongata* CARPENTER, 1857. Rare (3), dredged 17 fms. broken shell and rock bottom, valves only (P).
- 188 *Lucina excavata* CARPENTER, 1857. Dredged 10-40 fms. broken shell and rock bottom (1, 6), (B, P).
- 189 *Lucina* cf. *L. fenestrata* HINDS, 1845. Dredged 20-30 fms. (7), (P).
- 190 *Lucina liana* (PILSBRY, 1931). Uncommon (3, 4, 6), dredged 15-100 fms. broken shell and rock bottom (D, P, S).
- 192 *Lucina approximata* (DALL, 1901). Uncommon (7), dredged 7 - 20 fms. silty bottom (K).
- 194 *Lucina leucocymoides* (LOWE, 1935). Dredged 10 fms. (1), valves only (P).
- 195 *Lucina undatoides* HERTLEIN & STRONG, 1945. Rare (1, 3, 4), dredged 10-17 fms. broken shell and rock bottom (P).
- 196 *Anodontia edentuloides* (VERRILL, 1870). Common (2, 3, 5, 6), dredged 10-100 fms. broken shell and rubble bottom (D, K, P, S, SBM).
- 200 *Codakia distinguenda* (TRYON, 1872). Common (6, 9), diving 3-7 m; sand beach extreme low tide (D, M, P, SBM).
- 201 *Ctena chiquita* (DALL, 1901). Common (3, 4, 6, 8), intertidal on sand bars; dredged 10-17 fms. broken shell and rock bottom (D, P, SBM).
- 202 *Ctena clarionensis* HERTLEIN & STRONG, 1946. Rare (3, 6), dredged 17 fms. broken shell and rock bottom (P, SBM).
- 204\* *Ctena galapagana* (DALL, 1901). Rare (3), dredged 15-17 fms. broken shell bottom; Nicaragua (D, P).
- 205 *Ctena mexicana* (DALL, 1901). Uncommon (2, 3, 4, 6, 9), dredged 7-20 fms. broken shell and rock bottom; intertidal sand beach (D, K, M, P, SBM).
- 206 *Divalinga eburnea* (REEVE, 1850). Uncommon (3, 4, 6), dredged 10-100 fms. broken shell and rubble bottom (D, P).
- 208 *Diplodonta inezensis* (HERTLEIN & STRONG, 1947). Rare (3), dredged 17 fms. broken shell and rock bottom (P).
- 210 *Diplodonta subquadrata* CARPENTER, 1856. Common (2, 3, 4, 6), dredged 10-50 fms. broken shell bottom (D, K, P, S, SBM).
- 214 *Diplodonta semirugosa* DALL, 1899. Rare (3, 4), dredged 10-17 fms. broken shell bottom (P).
- 215 *Erycina colpoica* DALL, 1913. Rare (5), dredged 15 fms. silt bottom (SBM).  
*Cymatinoa electilis* (BERRY, 1963). Buried in muddy sand under rocks 10 m below surface, SHASKY, 1964 (6).
- 216 *Aligena cokeri* DALL, 1909. Rare (1, 3), dredged 10-20 fms., valves only (P).
- 218 *Basterotia peninsularis* JORDAN, 1936. Dredged 17 fms. rock and gravel bottom, valves only (1), (P).
- 221 *Ensitellops hertleini* EMERSON & PUFFER, 1957. Rare (5), dredged 15 fms. silt bottom (SBM).
- 231 *Mysella compressa* (DALL, 1913). Intertidal among rocks and sand (5), (B).
- 236 *Solecardia eburnea* CONRAD, 1849. Uncommon (1, 5), diving 3-7 m; intertidal on sand beach (D, M).
- 237 "*Sportella*" *stearnsii* DALL, 1891. Rare (4), dredged 10-15 fms. broken shell bottom (P).
- 238 *Chama buddiana* C. B. ADAMS, 1852. Common (2, 3, 5, 6), intertidal attached to rocks; dredged 17 fms. (B, D, M, P, SBM).
- 240a *Chama frondosa mexicana* CARPENTER, 1857. Rare (2, 5), intertidal attached to rocks (B, P).
- 241 *Chama sordida* BRODERIP, 1835. Uncommon (3, 6), dredged 17-25 fms. broken shell and rock bottom (B, D, P).
- 242 *Chama squamuligera* PILSBRY & LOWE, 1932. Un-

- common (2, 4, 6, 8), intertidal on rocks; dredged 100 fms. rubble bottom (D, K, P, SBM).
- 244 *Arcinella californica* (DALL, 1903). Uncommon (3, 5, 6), dredged 10-20 fms. silt and broken shell bottom (B, P, SBM).
- 248 *Pseudochama saavedrai* HERTLEIN & STRONG, 1946. Rare (3, 6), dredged 17 fms. (B, P).
- 249\* *Trachycardium consors* (SOWERBY, 1833). Rare (1, 3, 4, 6), dredged 7-45 fms.; diving 3-7 m; southern Gulf of California (K, M, P).
- 251 *Trachycardium senticosum* (SOWERBY, 1833). Uncommon (2, 3), intertidal on sand bars; dredged 17 fms., valves only (D, P).
- 252 *Trachycardium panamense* (SOWERBY, 1833). Common (2, 4, 5), intertidal, sand beach (B, D, P, SBM).
- 254 *Trachycardium belcheri* (BRODERIP & SOWERBY, 1829). Common (3, 5, 6), dredged 10-100 fms. silt and rubble bottom (B, D, K, P, S, SBM).
- 255 *Papyridea aspersa* (SOWERBY, 1833). Common (1, 2, 3, 4, 5), intertidal on sand beaches; dredged 6-20 fms. gravel, rock and broken shell bottoms (D, K, M, P).
- 256 *Trigoniocardia granifera* (BRODERIP & SOWERBY, 1829). Uncommon (3, 4, 5, 6), dredged 6-100 fms. rubble, broken shell and rock bottoms (D, K, P, S, SBM).
- 258 *Trigoniocardia biangulata* (BRODERIP & SOWERBY, 1829). Common (2, 3, 4, 5, 6), intertidal, sand beach; dredged 6-100 fms. rubble, broken shell and rock bottoms; diving 3-7 m; sand beach, low tide (D, K, M, P, S, SBM).
- 261 *Laevicardium clarionense* (HERTLEIN & STRONG, 1947). Uncommon (3, 4, 5, 6), dredged 10-25 fms. silty bottom (B, P, S).
- 262 *Laevicardium elatum* (SOWERBY, 1833). Uncommon (2, 4, 5, 6), dredged 10 fms. silty bottom (B, S, SBM).
- 263 *Laevicardium elenense* (SOWERBY, 1840 [? 1841]). Common (3, 4, 5, 6, 9), dredged 7-100 fms. silt, rubble, and broken shell bottoms; diving 3-7 m; intertidal sand beach (B, K, M, P, SBM).
- 264 *Lophocardium annettae* (DALL, 1889). Uncommon (3, 5, 6), dredged 10-25 fms. silt bottom (B, K, P, S, SBM).
- 266 *Nemocardium pazianum* (DALL, 1916). Uncommon (2, 3, 5, 6), dredged 10-100 fms. broken shell and rock bottom; intertidal, silty beach (D, K, P, S).
- 267 *Periglypta multicostata* (SOWERBY, 1835). Uncommon (5, 6, 8), dredged 20-40 fms.; intertidal among rocks in sand; diving 2-7 m (B, D, M, P).
- 268 *Ventricolaria isocardia* (VERRILL, 1870). Uncommon (2, 3, 4), dredged 10-17 fms. broken shell and rock bottom; intertidal among rocks (D, P).
- 270\* *Gouldia californica* DALL, 1917. Common (2, 3, 6), dredged 17 fms. broken shell and rock bottom; La Paz (D, P, S).
- 273 *Tivela byronensis* (GRAY, 1838). Common (4, 6, 9), intertidal sand beach (B, D, K, P, S).
- 281 *Transennella sororcula* PILSBRY & LOWE, 1932. Uncommon (1, 3, 4), dredged 17 fms. broken shell and rock bottom (B, P).
- 282 *Transennella tantilla* (GOULD, 1853). Rare (6), (SBM).
- 285 *Pitar fluctuatus* (SOWERBY, 1851). Rare (3, 4), dredged 10-17 fms. gravel bottom (P).
- 286 *Pitar newcombianus* (GABB, 1865). Common (1, 6), dredged 10-25 fms. broken shell and sand bottom; diving 3-7 m (D, K, M, P).
- 287\* *Pitar* sp., possibly new, labelled in collections as *P. perfragilis* (not the *P. perfragilis* of PILSBRY & LOWE, 1932, *teste* KEEN, 1965, after examination of the holotype). Uncommon (3, 6), dredged 15-25 fms. broken shell bottom; Nicaragua (B, D, K, P, S).
- 290\* *Pitar aletes* HERTLEIN & STRONG, 1948. Rare (3), dredged 17 fms. broken shell and rock bottom; southern Gulf of California (B, P).
- 292 *Pitar lupanaria* (LESSON, 1830). Low tide, sand beach (9), (B, D, P, S, SBM).
- 293 *Pitar roseus* (BRODERIP & SOWERBY, 1829). Rare (6), dredged 15-20 fms. (B, D).
- 296 *Pitar concinnus* (SOWERBY, 1835). Uncommon (1, 4, 9), dredged 10 fms. broken shell and rock bottom; intertidal sand beach (P).
- 299 *Pitar catharius* (DALL, 1902). Rare (6), dredged 45-100 fms. rubble bottom (S).
- \* *Pitar helenae* OLSSON, 1961. Rare (3), dredged 17 fms. broken shell and rock bottom; Panama (P).
- 302 *Megapitaria aurantiaca* (SOWERBY, 1831). Rare (3), dredged 17 fms. broken shell and rock bottom (P).
- 303 *Megapitaria squalida* (SOWERBY, 1835). Common (1, 2, 3, 4, 5, 6), dredged 10-100 fms. varied bottoms; diving 3-7 m; intertidal sand beach (B, D, K, M, P, S, SBM).
- 305 *Dosinia dunkeri* (PHILIPPI, 1844). Common (2, 3, 4), dredged 17 fms. broken shell and rock bottom (B, D, K, M, P, SBM).
- 306 *Dosinia ponderosa* (GRAY, 1838). Rare (4), in estero (B).
- 307a\* *Cyclinella kroeyeri ulloana* HERTLEIN & STRONG, 1948. Rare (3), dredged 17 fms. broken shell and rock bottom; southern Gulf of California (P).

- 309 *Cyclinella singleyi* DALL, 1902. Rare (3, 6), dredged 7-25 fms. (K, S).
- 310 *Cyclinella subquadrata* (HANLEY, 1845). Rare (3, 6, 9), dredged shell and gravel bottom; intertidal sand beach (B, D, S).
- 318 *Chione californiensis* (BRODERIP, 1835). Common (2, 4, 5, 9), in sandy estero, low tide (B, D, K, M, P, SBM).
- 319 *Chione compta* (BRODERIP, 1835). Common (2, 3, 4, 5, 6, 8, 9), dredged 15 fms. broken shell and rock bottom; intertidal sand beach (B, D, K, P, SBM).
- 320\* *Chione guatulcoensis* HERTLEIN & STRONG, 1948. Rare (9), intertidal sand beach; Port Guatulco, Mexico (P).
- 321 *Chione undatella* (SOWERBY, 1835). Common (2, 4, 6), muddy estero, low tide (B, D, K, M, P, S, SBM).
- 323 *Chione fluctifraga* (SOWERBY, 1853). Uncommon (2, 9), intertidal, sand beach (D, S, SBM).
- 324 *Chione amathusia* (PHILIPPI, 1844). Sand beach, low tide (4), (K).
- 326 *Chione gnidia* (BRODERIP & SOWERBY, 1829). Common (4, 8), intertidal, muddy estero (B, D, P, S).
- 328 *Chione purpurissata* DALL, 1902. Intertidal on sand flats (2), (B).
- 329 *Chione traftoni* PILSBRY & OLSSON, 1941. Beach valves (9), (P).
- 330 *Chione kellestii* (HINDS, 1845). Uncommon (6), dredged 15-100 fms. rubble bottom; intertidal among rocks (B, D, K, P, S).
- 331 *Chione mariae* (ORBIGNY, 1845). Common (3, 4, 5, 6), dredged 7-100 fms. rubble, broken shell and rock bottoms (B, D, K, P, S).
- 335 *Chione picta* WILLETT, 1944. Uncommon (3, 4, 5), dredged 10-17 fms. broken shell and rock bottom (B, P).
- 336\* *Anomalocardia subimbricata* (SOWERBY, 1835). Rare (5), in estero; La Paz (SBM).
- 337\* *Anomalocardia tumens* (VERRILL, 1870). Uncommon (2, 5, 6), intertidal under rocks; southern Gulf of California (B, M, P, SBM).
- 338 *Anomalocardia subrugosa* (WOOD, 1828). Uncommon (2, 4, 9), muddy esteros (B, D, K, P).
- 340 *Protothaca grata* (SAY, 1831). Uncommon (2, 4, 9), mud flats (B, M, P, SBM).
- 341 *Protothaca asperima* (SOWERBY, 1835). Intertidal in estero (4), (B).
- 348 *Petricola parallela* PILSBRY & LOWE, 1932. Uncommon (9), in hard mud flats (B, K, P).
- 355 *Macra dolabriliformis* (CONRAD, 1867). Uncommon (4, 5), sand beach (D, SBM).
- 358 *Macra californica* CONRAD, 1837. Uncommon (6), dredged 45 fms. broken shell bottom (K, S).
- 359\* *Macra fonssecana* HERTLEIN & STRONG, 1950. Dredged 15 fms. valves only (4); Nicaragua (P).
- 363 *Anatina cyprinus* (WOOD, 1828). Dredged 15-25 fms., valves only (6), (P).
- 364 *Anatina undulata* (GOULD, 1851). Common (9), sand beach, valves only (B, D, P, SBM).
- 371\* *Mulinia pallida* (BRODERIP & SOWERBY, 1829). Rare (4), in estero; Guatemala (B).
- 373 *Tellina pacifica* DALL 1900. Uncommon (4, 6), dredged 10-100 fms. rubble, broken shell and rock bottoms (K, P, S).
- 376 *Tellina inaequistriata* DONOVAN, 1802. Uncommon (1, 3, 6), dredged 10-100 fms. rubble, broken shell and rock bottoms (K, P).
- 384 *Tellina simulans* C. B. ADAMS, 1852. Uncommon (3, 5, 6), dredged 10-100 fms. rubble, broken shell and rock bottom (K, P).
- 386 *Tellina lyricea* PILSBRY & LOWE, 1932. Common (3, 6), dredged 17-100 fms. rubble, broken shell and rock bottoms (B, D, P, S).
- 390 *Tellina proclivis* HERTLEIN & STRONG, 1949. Common (5, 6), dredged 10-100 fms. rubble and silt bottom (B, D, K, S).
- 392 *Tellina amianta* DALL, 1900. Uncommon (4, 6), dredged 15-40 fms. (K, P).
- 393 *Tellina arenica* HERTLEIN & STRONG, 1949. Uncommon (3, 4), dredged 10-17 fms. rock and silt bottom (P).
- 397 *Tellina felix* HANLEY, 1844. Uncommon (2), (D, SBM).
- 398 *Tellina guaymasensis* PILSBRY & LOWE, 1932. Dredged in harbor (7), (B).
- 401\* *Tellina paziana* DALL, 1900. Common (3, 4, 5, 6), dredged 10-100 fms. silt, rubble, broken shell and rock bottoms; La Paz (D, K, P, S).
- 403 *Tellina recurvata* HERTLEIN & STRONG, 1949. Uncommon (3, 4, 6), dredged 15-40 fms. broken shell and rock bottom (K, P).
- 408 *Tellina pristiphora* DALL, 1900. Uncommon (6), dredged 20-100 fms. rubble, broken shell and rock bottoms (B, D, K, S).
- 413 *Tellina virgo* HANLEY, 1844. Intertidal in sand (4), (B).
- 414 *Tellina ochracea* CARPENTER, 1864. Uncommon (6), sand beach (SBM).
- 416 *Tellina cumingii* HANLEY, 1844. Rare (3, 5), dredged 15-17 fms. silt, broken shell and rock bottom (P).
- 418 *Tellina purpurea* BRODERIP & SOWERBY, 1829. Un-

- common (3, 4, 5), dredged 10-17 fms. broken shell and rock bottom; sand beach low tide (K, P).
- 423 *Apolymetis cognata clarki* DURHAM, 1950. Common (3, 5, 6), dredged 17-100 fms. rubble, broken shell and rock bottom; diving 3-7 m (B, D, M, P, SBM).
- 425 *Macoma undulata* (HANLEY, 1844). Uncommon (3, 4, 5, 6), dredged 10-40 fms. silt, broken shell and rock bottoms (K, P, SBM).
- 426 *Macoma medioamericana* OLSSON, 1942. Rare (6), dredged 45-100 fms. rubble, broken shell bottom (K, S).
- 428 *Macoma elytrum* KEEN, 1958. Rare (3, 6), dredged 17-100 fms. rubble, broken shell and rock bottoms (D, P).
- 432 *Macoma* cf. *M. lamproleuca* (PILSBRY & LOWE, 1932). Dredged 45-100 fms. (6), (S).
- 433 *Macoma siliqua* (C. B. ADAMS, 1852). Common (3, 4, 5, 6), dredged 17-100 fms. silt, rubble, and broken shell and rock bottoms (D, K, P, S).
- 433a *Macoma panamensis spectri* HERTLEIN & STRONG, 1949. Uncommon (6), dredged 100 fms., rubble bottom (D).
- 434 *Macoma aurora* (HANLEY, 1844). Uncommon (3, 4), dredged 10-17 fms. broken shell and rock bottom (D, P).
- 436 *Macoma pacis* PILSBRY & LOWE, 1932. Common (4, 6, 9), dredged 40-100 fms. rubble bottom; in estero; sand beach (B, K, P, SBM).
- 437\* *Macoma plebeia* (HANLEY, 1844). Sand beach low tide (4); Nicaragua (SBM).
- 438 *Strigilla cicercula* (PHILIPPI, 1846). Common (5, 9), sand beach (D, K, P).
- 439 *Strigilla dichotoma* (PHILIPPI, 1846). Intertidal in sand (4), (B).
- 441\* *Strigilla lenticula* PHILIPPI 1846. Rare (6), dredged 100 fms. rubble; Cape San Lucas (S).
- 442 *Tellidora burneti* (BRODERIP & SOWERBY, 1829). Uncommon (2, 4), dredged broken shell and rock bottom; in estero among *Pinna* near mangrove roots (B, D, P, SBM).
- 451 *Donax navicula* HANLEY, 1845. Sand beach low tide (1, 9), (D, P).
- 455 *Donax punctatostriatus* HANLEY, 1843. Common (4, 5, 9), sand beach low tide (B, D, K, P, S, SBM).
- 461 *Sanguinolaria purpurea* DESHAYES, 1855. Beach valves (4), (D).
- 462 *Sanguinolaria tellinoides* A. ADAMS, 1850. Rare (4), beach valves (D, K).
- 466 *Gari regularis* (CARPENTER, 1864). Uncommon (1, 3, 4, 6), dredged 10-100 fms. rubble, broken shell and rock bottom; diving 3-7 m (K, M, P).
- 467 *Heterodonax bimaculatus* (LINNAEUS, 1758). Sand beach (4), (K, S).
- 469 *Solecurtus guaymasensis* LOWE, 1935. Common (3, 4, 5, 6), dredged 5-100 fms. silt, rubble, broken shell and rock bottoms (B, D, K, P, S).
- 470 *Tagelus affinis* (C. B. ADAMS, 1852). Beach specimens (9), (B).
- 471 *Tagelus californianus* (CONRAD, 1837). Uncommon (4, 9), silty mud in estero, sand beach (B, P).
- 474 *Tagelus peruvianus* PILSBRY & OLSSON, 1941. Beach valves (9), (B).
- 475 *Tagelus politus* (CARPENTER, 1857). Common (3, 4, 5, 6), dredged 10-100 fms. rubble, silt, broken shell and rock bottoms (B, D, K, P, S).
- 479\* *Semele craneana* HERTLEIN & STRONG, 1949. Uncommon (3, 5), dredged 15-17 fms. broken shell and rock bottom; southern Gulf of California (P).
- 481 *Semele flavescens* (GOULD, 1851). Dug from among rocks at extreme low tide (8), (D).
- 482 *Semele formosa* (SOWERBY, 1832). Sand beach low tide (9), (P).
- 483 *Semele guaymasensis* PILSBRY & LOWE, 1932. Common (1, 2, 4, 5, 6, 9), dredged 10-40 fms. silt, rubble, broken shell and rock bottom (B, D, K, P, S, SBM).
- 485 *Semele jovis* (REEVE, 1853). Uncommon (3, 4, 5), dredged 10-17 fms. broken shell and rock bottom (B, D, P, S).
- 486 *Semele junonia* (VERRILL, 1870). Rare (1, 3, 5), dredged 10-17 fms. broken shell and rock bottom; diving 10 m (M, P).
- 489 *Semele pacifica* DALL, 1915. Common (3, 4, 6), dredged 15-50 fms. (D, P, S, SBM).
- 494 *Semele quentinensis* DALL, 1921. Intertidal on sand flats (2), (P).
- 497 *Semele simplicissima* PILSBRY & LOWE, 1932. Dredged 17 fms. broken shell and rock bottom (3, 6), (B, P).
- 498\* *Semele sparsilineata* DALL, 1915. Rare (3, 4), dredged 17 fms. broken shell and rock bottom; Nicaragua (B, P).
- 508 *Cumingia lamellosa* SOWERBY, 1833. Among rocks and sand (5), (B).
- 516 *Solen rosaceus* CARPENTER, 1864. Dredged 3 fms.; on mud flats in drainage channels (2, 9), (D, P).
- 518 *Ensis californicus* DALL, 1899. Dredged 10 fms. silt bottom; intertidal on sand (1, 4), (B, P).
- 522 *Corbula speciosa* REEVE, 1843. Common (1, 3, 4), dredged 10-17 fms. broken shell and rock bottom (B, D, P).

- 523 *Corbula bicarinata* SOWERBY, 1833. Intertidal (3), (B, M).
- 526 *Corbula marmorata* HINDS, 1843. Uncommon (3, 4, 5), dredged 10-17 fms., silt, broken shell and rock bottom (D, K, P, S).
- 527 *Corbula nasuta* SOWERBY, 1833. Uncommon (4), dredged 15 fms. broken shell and rock bottom (P).
- 529 *Corbula obesa* HINDS, 1843. Uncommon (3, 4, 6), dredged 10-40 fms. broken shell and rock bottom (B, P).
- 531 *Corbula porcella* DALL, 1916. Uncommon (4), dredged 15 fms. broken shell and rock bottom (P).
- 532 *Corbula ventricosa* ADAMS & REEVE, 1850. Rare (2, 3), dredged 2-3 fms. sand bottom; mud flats (P).
- 539 *Gastrochaena ovata* SOWERBY, 1834. Rare (5), (SBM).
- 540\* *Gastrochaena rugulosa* SOWERBY, 1834. Rare (1, 3), dredged 5 fms., on *Spondylus calcifer*; Galapagos Islands (P).
- 542 *Hiatella arctica* (LINNAEUS, 1767). Nestling in crevices (2), (K).
- 546 *Pholas chiloensis* MOLINA, 1782. In hard mud reef, low tide (9), (P).
- 547 *Barnea subtruncata* (SOWERBY, 1834). In hard mud reef, low tide (9), (K, P).
- 555 *Parapholas calva* (SOWERBY, 1834). Rare (3, 4), intertidal; dredged 17 fms. in rocks (B, P).
- 568\* *Pandora uncifera* PILSBRY & LOWE, 1932. Uncommon (3, 4, 5), dredged 10-17 fms. broken shell bottom; Cape San Lucas (P, S).
- 569 *Pandora claviculata* CARPENTER, 1855. Dredged 40 fms. shell bottom (6), (K).
- 576 *Pandora granulata* DALL, 1915. Dredged 15-17 fms. (3, 4), (P).
- 578 *Lyonsia gouldii* DALL, 1915. Dredged 3-15 fms. silty bottom (4, 5, 9), (P, S).
- 579 *Lyonsia inflata* CONRAD, 1837. Dredged 17 fms. broken shell and rock bottom (3), (P).
- 583 *Periploma discus* STEARNS, 1890. Beach specimens (4), (B).
- 585 *Periploma planiusculum* SOWERBY, 1834. Valves only, dredged 15 fms. (4, 9), (B, K, P).
- 588 *Thracia colpoica* DALL, 1915. Beach valves (9), (P).
- 595\* *Cyathodonta undulata* CONRAD, 1849. Uncommon (3, 4), dredged 15-17 fms. broken shell and rock bottom; southern Gulf of California (B, P).
- 598 *Cuspidaria dulcis* PILSBRY & LOWE, 1932. Uncommon (3, 4, 5), dredged 7-17 fms. broken shell and rock bottom (D, K, P, S, SBM).
- 599\* *Cuspidaria lanieri* STRONG & HERTLEIN, 1937. Rare. (3, 4, 6), dredged 15-100 fms. rubble, broken shell

and rock bottom; Cape San Lucas (P, S).

- 601 *Plectodon scaber* CARPENTER, 1864. Dredged 20-100 fms. rubble, silt bottom, valves only (P, S).

- 606 *Solemya valvulus* CARPENTER, 1864. Uncommon (3, 5), dredged 10-17 fms. silty sand and shell bottom (P).

#### SCAPHOPODA

- 2 *Dentalium inversum* DESHAYES, 1826. (5), projecting from sand (D).
- 3 *Dentalium oerstedii* MÖRCH, 1860. Common (1, 2, 3, 5, 6), dredged 6-40 fms. (D, K, P).
- 5 *Dentalium sectum* DESHAYES, 1826. (2), projecting from sand, extreme low tide (D).
- 6 *Dentalium* cf. *D. semipolatum* BRODERIP & SOWERBY, 1829. Uncommon (3, 4), dredged 10-17 fms. on rock and silt bottom (P).
- 7 *Dentalium splendidum* SOWERBY, 1832. Uncommon (3, 6), dredged 17-60 fms. on rock and gravel bottom (P, S).
- 9 *Dentalium quadrangulare* SOWERBY, 1832. (3, 5), dredged 6-15 fms. (D, K, SBM).
- 10\* *Dentalium tesseragonum* SOWERBY, 1832. Common (1, 3, 4), dredged 10-17 fms. on rock and broken shell bottom; Manzanillo (D, P).
- 11 *Cadulus austinclarki* EMERSON, 1951. Rare (3), dredged 17 fms. on rock and gravel bottom (D, P).
- 12 *Cadulus panamensis* PILSBRY & SHARP, 1897. Uncommon (1, 3, 5), dredged 10-20 fms. on sand and rubble bottom (D, P, SBM).

#### GASTROPODA

- 2 *Acmaea atrata* CARPENTER, 1857. Common (2, 6), upper intertidal zone on rocks (B, K, P, SBM).
- 4 *Acmaea fascicularis* (MENKE, 1851). Uncommon (6), intertidal on rocks (B).
- 7a *Acmaea fayae* HERTLEIN, 1958. Common (2), intertidal on rocks; uncommon diving 6-12 m (D, M, P, S, SBM).
- 10 *Acmaea semirubida* DALL, 1914. Rare (5), low tide under rocks; dredged 5 fms. on dead shells; diving 6m (B, M, SBM).
- 12 *Acmaea strigatella* CARPENTER, 1857. Common (1, 6, 7), intertidal among rocks; diving 6-12 m (B, M, S, SBM).
- 14 *Acmaea turveri* HERTLEIN & STRONG, 1951. Common (1, 2, 6), intertidal among rocks (B, D, P, S, SBM).
- 16 *Nomaeopelta dalliana* (PILSBRY, 1891). Rare (5, 6), on rocks at mid-tide (K).

- 18 *Nomacopelta stanfordiana* (BERRY, 1957). Common (6), intertidal among rocks (D, S, SBM).
- 25 *Fissurella* cf. *F. rugosa* SOWERBY, 1835 (wrong illustration in KEEN, 1958). Uncommon (6), intertidal on rocks (M).
- Lucapinella eleanorae* McLEAN, 1967. Uncommon (1), dredged 20 fms.; type locality (M, P).
- \* *Lucapinella milleri* BERRY, 1959. Common (1, 3, 4), on rocks just below low tide; dredged 17 fms. on rock and gravel bottom; Puertecitos, Gulf of California (B, M, P).
- 30 *Diodora alta* (C. B. ADAMS, 1852). Common (2, 3, 4, 6), dredged 17-30 fms. on rock and gravel bottom; diving 6-12 m (K, M, P, SBM).
- 32 *Diodora inaequalis* (SOWERBY, 1835). Uncommon (2, 3, 4, 5, 6), intertidal under rocks; common dredged 7-20 fms. on rock bottom (B, D, K, M, P, S).
- 34 *Diodora saturnalis* (CARPENTER, 1864). Uncommon (2, 3, 6), intertidal under rocks; common dredged 17 fms. on rock and broken shell bottom; diving 6-12 m (M, P, SBM).
- \* *Diodora pusilla* BERRY, 1959. Common (1, 3, 4, 5), dredged 10-17 fms. on rock and broken shell bottom; Acapulco, Mexico (D, M, P, SBM).
- 35\* *Stromboli beebei* (HERTLEIN & STRONG, 1951). Rare (6), dredged 40-90 fms. on rubble bottom; Gorda Banks, southern part of Gulf of California (B, D, K, S).
- 37 *Hemitoma hermosa* LOWE, 1935. Common (1, 3, 4), dredged 10-30 fms. on rock and gravel bottom (D, P).
- \* *Sinezona rimuloides* CARPENTER, 1865. (5), in sand siftings; Mazatlan, Mexico (B).
- 39 *Calliostoma antonii* (KOCH in PHILIPPI, 1843). Rare (1), dredged 10 fms. on rock and gravel bottom (P).
- 41 *Calliostoma eximium* (REEVE, 1843). Uncommon (3, 4, 8, 9), intertidal on weed and sand bars; dredged 17 fms. on rock bottom (B, D, K, M, P, S).
- 42 *Calliostoma leanum* (C. B. ADAMS, 1852). Uncommon (4, 6, 8), among small stones on sand beach; dredged 45-100 fms. (B, D, S).
- 45 *Calliostoma marshalli* LOWE, 1935. Uncommon (1, 3), dredged 10-20 fms. on rock and gravel bottom (P).
- 47 *Calliostoma palmeri* DALL, 1871. Common (6, 7, 9), in rocky rubble at low tide; uncommon dredged 7-40 fms. (B, D, K).
- Calliostoma mcleani* SHASKY & CAMPBELL, 1964. Uncommon (1, 3, 4), dredged 17 fms. on rock and gravel bottom; diving 15-17m; type locality (D, P).
- Turcica caffee* GABB, 1865. Rare (6), dredged 50-100 fms. on sand and broken shell bottom (D, K, S).
- 48\* *Astele rema* (STRONG, HANNA & HERTLEIN, 1933). (6), under rocks at low tide; Mazatlan (SBM).
- 54 *Tegula mariana* DALL, 1919. Extremely common (1, 2, 5, 6, 8), intertidal under rocks; common diving (B, D, M, P, SBM).
- 57 *Tegula rubroflammulata* (KOCH in PHILIPPI, 1843). Uncommon (1, 6, 7, 8, 9), inside dead shells at low tide (B, D, M, P, SBM).
- 58 *Tegula rugosa* (A. ADAMS, 1853). Common (2, 6), on rocks above splash zone (D, K, M, P, S, SBM).
- 60 *Solariella triplostephanus* DALL, 1910. Rare (1, 3, 4, 6), intertidal among weed on rock; dredged 10-40 fms. on gravel and broken shell bottom (B, K, P, S).
- 64 *Turbo fluctuosus* WOOD, 1828. Common (2, 4, 6, 9), intertidal among rocks (B, D, K, M, P, SBM).
- 68 *Turbo squamiger* REEVE, 1843. Uncommon (1), dredged 10 fms. on rock and gravel bottom; diving 6-12 m (M, P).
- 76 *Astraea unguis* (WOOD, 1828). Common (2, 4, 6), intertidal among rocks; uncommon dredged 45 fms. (B, D, K, M, P, S, SBM).
- \* *Homalopoma conceptionensis* LOWE, 1935. Uncommon (3), dredged 17 fms. on rock and gravel bottom; Concepcion Bay, Gulf of California (D, P).
- \* *Tricolia cyclostoma* CARPENTER, 1864. Uncommon (4, 5), among rocks at low tide; diving 6-12 m; Cape San Lucas, Lower California (M, SBM).
- \* *Tricolia substriata* (CARPENTER, 1864). Uncommon (5), intertidal among rocks and sand; Cape San Lucas, Lower California (B).
- \* *Tricolia variegata* (CARPENTER, 1864). Rare (3, 4, 6), on rock in mouth of estero; dredged 17 fms. on broken shell and rock bottom; diving 6-12 m; Cape San Lucas, Lower California (D, M, P).
- 77\* *Arene* cf. *A. hindsiana* PILSBRY & LOWE, 1932. Rare (2, 3), intertidal under rocks; dredged 7-20 fms.; Nicaragua (D, K).
- \* *Arene rammata* (DALL, 1918). Common (5, 6), intertidal under rocks; diving 6-12 m; Magdalena Bay, Lower California (D, M).
- 81 *Nerita scabricosta* LAMARCK, 1822. Common (2, 4, 5, 6), intertidal on rocks (B, D, K, M, P, SBM).
- 82 *Nerita funiculata* MENKE, 1851. Uncommon (4, 6), intertidal on rocks (D, M, S, SBM).
- 83 *Neritina luteofasciata* MILLER, 1879. Common (2, 4, 6), intertidal under rocks and among mangrove trees (B, D, K, M, P, SBM).
- 85 *Phenacolepas malonei* VANATTA, 1912. Rare (1, 5, 6), intertidal on rocks; dredged 10 fms. on rock bottom (D, P, SBM).



- 86 *Phenacolepas osculans* (C. B. ADAMS, 1852). Rare (2, 6), intertidal on shells and under rocks (P, SBM).
- \* *Eulima townsendi* (BARTSCH, 1917). Uncommon (3), dredged 15 fms. on rock and gravel bottom; La Paz, Lower California (B).
- Balcis mexicana* BARTSCH, 1917. Rare (2, 3), under rocks at extreme low tide; dredged 15-35 fms. on rock and gravel bottom (B, D, P).
- \* *Balcis panamensis* (BARTSCH, 1917). Rare (5), intertidal among rocks and sand; Panama (B).
- \* *Balcis yod* (CARPENTER, 1857). Rare (5), intertidal among rocks and sand; Mazatlan, Mexico (B).
- 87 *Niso excolpa* BARTSCH, 1917. Uncommon (1, 3, 4, 5, 6), dredged 10-60 fms. on rock and gravel bottom (B, D, K, P, S).
- 88\* *Niso interrupta* (SOWERBY, 1834). Rare (6), dredged 20-40 fms.; San Pedro Martir Island, Gulf of California (B).
- 89\* *Niso splendidula* (SOWERBY, 1834). Rare (3, 4), dredged 10-20 fms. on rock and gravel bottom; Angel de la Guarda Island, Gulf of California (B, P).
- 91 *Epitonium canna* DALL, 1919. Rare (6), intertidal under rocks (D).
- 98 *Epitonium vivesi* HERTLEIN & STRONG, 1951. Rare (3), dredged 5 fms. on sand bottom (D).
- 100\* *Epitonium xantusi* DALL, 1917. Rare (3, 6), dredged 17 fms. on rock and gravel bottom; diving 6-12 m; La Paz (M, P).
- \* *Epitonium emydonesus* DALL, 1917. Rare (6), intertidal under rocks; Galápagos Islands (SBM).
- 103 *Epitonium togatum* HERTLEIN & STRONG, 1951. Rare (4), dredged 10 fms. on rock and gravel bottom (dead specimen) (P).
- Epitonium pentadesmium* BERRY, 1963. Rare (3), dredged 15 fms. on rock and gravel bottom; type locality (B, D, P).
- 107 *Epitonium appressicostatum* DALL, 1917. Rare (1), dredged 10 fms. on gravel bottom (P).
- 108 *Epitonium* cf. *E. barbarinum* DALL, 1919. Uncommon (3, 5), intertidal under rocks; dredged 10 fms. on rock bottom (dead specimens) (P).
- 113\* *Epitonium colpoicum* DALL, 1917. Rare (6), intertidal; La Paz, Lower California (D).
- 118\* *Epitonium durhamianum* HERTLEIN & STRONG, 1951. Rare (5), under rocks at low tide; Nicaragua (SBM).
- 124 *Epitonium oerstedianum* HERTLEIN & STRONG, 1951. Rare (3, 4, 5), dredged 17 fms. on rock and gravel bottom; diving 6-12 m (B, D, M, P, SBM).
- 135 *Epitonium wurtsbaughi* STRONG & HERTLEIN, 1939. Common (1, 3, 4, 6), dredged 10-60 fms on rock and gravel bottom (B, D, P, SBM).
- 137 *Epitonium carpenteri* (TAPPARONE-CANEVRI, 1876). Rare (6), under rocks at low tide (SBM).
- \* *Epitonium replicata* SOWERBY, 1844. Rare (3), dredged 17 fms. on rock and gravel bottom (dead specimen); Galápagos Islands (P).
- 156 *Opalia crenatoides* (CARPENTER, 1864). Rare (6), intertidal under rocks (SBM).
- 157 *Opalia crenimarginata* (DALL, 1917). Rare (3), intertidal under rocks (dead specimen) (B).
- 158\* *Opalia diadema* (SOWERBY, 1832). Common (2, 6), intertidal under rocks; Mazatlan (D, P, SBM).
- 159 *Opalia golischi* (BAKER, HANNA & STRONG, 1930). Rare (6), intertidal under rocks (D).
- 161 *Opalia espirita* (BAKER, HANNA & STRONG, 1930). Rare (3), dredged 20 fms. on rock and sand bottom (dead specimen) (P).
- 165 *Opalia retiporosa* CARPENTER, 1864. Rare (3), dredged 10 fms. on gravel bottom (dead specimen) (P).
- 166\* *Opalia sanjuanensis* (LOWE, 1932). Rare (1), dredged 10 fms. on gravel bottom; Nicaragua (P).
- 167a *Scalina ferminiana brunneopicta* (DALL, 1908). Uncommon (3, 6), dredged 10-90 fms. on broken shell and gravel bottom (B, D, P).
- \* *Scalina billeeana* DUSHANE & BRATCHER, 1965. Rare (6), from sand siftings; Cerralvo Island, Gulf of California (B).
- 168 *Janthina globosa* BLAINVILLE, 1822. (9), beach specimens (B, P).
- 169 *Janthina janthina* (LINNAEUS, 1758). (9), beach specimens (B, P).
- 170 *Janthina prolongata* BLAINVILLE, 1822. (9), beach specimens (B).
- 173 *Littorina aspera* PHILIPPI, 1846. Common (6), on rocks in splash zone (D, M, SBM).
- 174 *Littorina conspersa* PHILIPPI, 1847. Uncommon (2, 6), intertidal on rocks (D, M, P, S).
- 175 *Littorina dubiosa* C. B. ADAMS, 1852. Common (2), on rocks in splash zone (M, P, S).
- 175a *Littorina dubiosa penicillata* CARPENTER, 1864. Common (2, 6), on rocks in splash zone (D, SBM).
- 177 *Littorina pullata* CARPENTER, 1864. Uncommon (2, 6), on rocks in splash zone (P, SBM).
- \* *Alvania monserratensis* BAKER, HANNA & STRONG, 1930. (5), in sand siftings; Monserrate Island, Gulf of California (B).
- \* *Allcorus deprellus* STRONG, 1938. (6), diving 6-12 m; San Jose Island, Gulf of California (M).



- \* *Cyclostremiscus trigonatus* (CARPENTER, 1856). (5), among rocks and sand; Mazatlan, Mexico (B).
- \* *Cyclostremiscus major* PILSBRY & OLSSON, 1952. (2, 6), dredged 7-20 fms. on silt and sand bottom; Panama (K, SBM).
- \* *Cyclostrema spiceri* BAKER, HANNA & STRONG, 1938. (5, 6), among rocks and sand; diving 6-12 m; Concepcion Bay, Gulf of California (B, M).
- \* *Episcynia nicholsoni* STRONG & HERTLEIN, 1939. Uncommon (3, 4), in mouth of estero; dredged 17 fms. on rock and shell bottom; Panama (B, P).
- \* *Macromphalina occidentalis* (BARTSCH, 1907). (1), dredged 10 fms. on rubble bottom; Point Abrejos, Lower California (P).
- \* *Macromphalina symmetrica* PILSBRY & OLSSON, 1945. Uncommon (3, 4), dredged 15-17 fms. on rock and gravel bottom; Ecuador (B, P).
- \* *Parviturboides copiosus* (PILSBRY & OLSSON, 1945). (5), among rocks and sand; Panama - Ecuador (B).
- \* *Solariorbis ditropis* PILSBRY & OLSSON, 1952. (*Cyclostremiscus?*) (5), among rocks and sand; Colombia (B).
- \* *Solariorbis elegans* PILSBRY & OLSSON, 1952. (6), among rocks and sand; Ecuador (B).
- \* *Solariorbis seminudus* (C. B. ADAMS, 1852). (5), in sand siftings; Panama (B).
- \* *Teinostoma amplexans* CARPENTER, 1856. (2, 5), among rocks and sand; Mazatlan, Mexico (B, D, M).
- \* *Teinostoma gallegosi* JORDAN, 1936. Uncommon (1, 5, 6), among rocks; Pleistocene, Magdalena Bay, Lower California (D, M).
- \* *Teinostoma regularis* (C. B. ADAMS, 1852). (6), under rocks at low tide; Panama (SBM).
- Vitrinella dalli* (BARTSCH, 1911). (5), among rocks and sand (B).
- \* *Vitrinella goniomphala* PILSBRY & OLSSON, 1952. (5), among rocks and sand; Ecuador (B).
- \* *Vitrinella guaymasensis* DURHAM, 1942. Rare (6), under rocks; Concepcion Bay, Lower California (SBM).
- \* *Amphithalamus inclusus* CARPENTER, 1864. (5), among rocks and sand; Santa Barbara, California (B).
- \* *Barleeia alderi* (CARPENTER, 1857). (5), among rocks and sand; diving 6-12 m; Mazatlan, Mexico (B, M).
- \* *Barleeia bentleyi* BARTSCH, 1920. (5), among rocks and sand; Venice, California (B).
- \* *Barleeia bifasciata* (CARPENTER, 1857). (5), in sand siftings; Mazatlan, Mexico (B).
- \* *Barleeia subtenuis* CARPENTER, 1864. Rare (6), under rocks; San Diego, California (SBM).
- \* *Rissoina barthelowi* BARTSCH, 1915. Uncommon (3), dredged 17 fms. on rock and broken shell bottom; Concepcion Bay, Lower California (D).
- \* *Rissoina expansa* CARPENTER, 1857. Rare (6), under rocks; Mazatlan, Mexico (SBM).
- \* *Rissoina firmata* (C. B. ADAMS, 1852). (5), among rocks and sand; Panama (B).
- \* *Rissoina stricta* (MENKE, 1850). Common (1, 2, 5, 6), under rocks, in colonies, at low tide; Mazatlan, Mexico (B, D, M, S).
- \* *Jeffreysia tumens* CARPENTER, 1857. (5, 6), under rocks and in sand siftings; Mazatlan, Mexico (B, SBM).
- 181 *Turritella banksi* REEVE, 1849. Uncommon (3, 9), intertidal on sand beach; dredged 17 fms. on rock and gravel bottom (D, K, P).
- 182 *Turritella clarionensis* HERTLEIN & STRONG, 1951. Uncommon (3, 4, 5, 6), dredged 15-25 fms. on rock, gravel and sand bottom (K, P, S, SBM).
- 183 *Turritella gonostoma* VALENCIENNES, 1832. Common (2, 4, 8, 9), intertidal on sand bars (B, D, K, M, P, SBM).
- 184 *Turritella lentiginosa* REEVE, 1849. (6), intertidal (SBM).
- 185 *Turritella leucostoma* VALENCIENNES, 1832. Common (3, 4, 5, 6, 9), intertidal on sand and mud flats; dredged 7-25 fms. on sand and silt bottom (B, D, K, P, S).
- 186 *Turritella mariana* DALL, 1908. Common (3, 6), dredged 15-20 fms. on sand and gravel bottom (B, D, K, P).
- 187 *Turritella nodulosa* KING & BRODERIP, 1832. Common (3, 5, 6), dredged 15-25 fms. on sand and gravel bottom (D, K, M, P, SBM).
- \* *Turritella sanguinea* REEVE, 1849. Rare (6), dredged 20-30 fms. on sand and rubble bottom (K).
- 189a *Vermicularia pellucida eburnea* (REEVE, 1842). Common (6, 8), attached under rocks (D, SBM).
- 191 *Architectonica nobilis* RÖDING, 1798. Uncommon (3, 4, 5, 6, 9), intertidal on rocks around pools; common dredged 10-100 fms. (B, D, K, P, S, SBM).
- 192 *Architectonica placentalis* (HINDS, 1844). Uncommon (1, 3, 6), dredged 10-100 fms. on sand and rubble bottom (D, K, P).
- 193 *Helicacis bicanaliculatus* (VALENCIENNES, 1832). Rare (2), intertidal under rocks (B, P).
- 194 *Helicacis mazatlanicus* PILSBRY & LOWE, 1932. Rare (1, 3, 5), dredged 10-20 fms. on rock and gravel bottom (D, P, SBM).

- \* *Heliacus chiquita* PILSBRY & LOWE, 1932. Rare (3, 5), in sand siftings; dredged 17 fms. on rock and gravel bottom; Acapulco, Mexico (B, P).
- \* *Heliacus planispira* PILSBRY & LOWE, 1932. Rare (3), dredged 17 fms. on rock and gravel bottom; Mazatlan, Mexico (P).
- \* *Caecum bahiahondaense* STRONG & HERTLEIN, 1939. (5), among rocks and sand; Panama (B).
- \* *Caecum clathratum* CARPENTER, 1857. (5), among rocks and sand; Mazatlan, Mexico (B).
- \* *Caecum heptagonum* CARPENTER, 1857. (5), in sand siftings; Mazatlan, Mexico (B).
- \* *Caecum liracinctum* CARPENTER, 1857. (5), in sand siftings; Mazatlan, Mexico (B).
- 195 *Modulus catenulatus* (PHILIPPI, 1849). Common (2, 3, 4, 8), intertidal on mud among mangroves and around rocks; uncommon dredged 10-17 fms. on rock and gravel bottom (B, D, K, M, P).
- 196 *Modulus cerodes* (A. ADAMS, 1851). Uncommon (1, 2, 3, 4, 6, 8), intertidal under rocks; dredged 10-17 fms. on rock and gravel bottom (D, K, M, P, SBM).
- 197 *Modulus disculus* (PHILIPPI, 1846). Common (2, 3, 4, 8), on mud flats; dredged 7-20 fms. on rock and gravel bottom (D, K, M, P).
- 200 *Petalonchus contortus* (CARPENTER, 1857). (8), attached to rocks (D).
- 203 *Petalonchus macrophragma* CARPENTER, 1865. Rare (6), attached to rocks (SBM).
- 205\* *Serpulorbis margaritaceus* CHENU, 1844. Uncommon (6), attached to rocks; Mazatlan, Mexico (B, SBM).
- 206 *Serpulorbis oryzata* (MÖRCH, 1862). (6), intertidal on rocks (B).
- 208 *Vermetus tripsyche* PILSBRY & LOWE, 1932. (3), dredged 15 fms. (B).
- 209\* *Cerithium adustum* KIENER, 1841. (2, 6), intertidal under rocks; Mazatlan, Mexico (K, P, S, SBM).
- 210 *Cerithium gemmatum* (HINDS, 1844). Uncommon (3), dredged 17 fms. on rock and gravel bottom (P, S).
- 211 *Cerithium maculosum* KIENER, 1841. Common (2, 4, 6), intertidal among rocks (D, M, P, S, SBM).
- 212 *Cerithium menkei* CARPENTER, 1857. Uncommon (2), intertidal under rocks (P, SBM).
- 214 *Cerithium sculptum* SOWERBY, 1855. Common (2, 3, 4, 6), intertidal under rocks; dredged 10-30 fms. on rock and gravel bottom (B, D, K, M, P, SBM).
- 215 *Cerithium stercusmuscarum* VALENCIENNES, 1833. Very common (1, 2, 4, 5, 8), under and around rocks (D, M, P, SBM).
- 216 *Cerithium uncinatum* (GMELIN, 1791). Uncommon (3, 6), intertidal under rocks; dredged 17 fms. on rock bottom (B, D, K, M, P, SBM).
- \* *Triphora contrerasi* F. BAKER, 1926. (5), among rocks and sand; San Evaristo Bay, Lower California (B).
- \* *Seila assimolata* C. B. ADAMS, 1852. Common (3, 6), intertidal, among rocks and sand; dredged 17 fms. on rock and gravel bottom; Puertecitos, Gulf of California (B, D, M, P).
- \* *Alaba interruptelineata* PILSBRY & LOWE, 1932. (6), intertidal under rocks; diving 6-12 m; Nicaragua (D, M, SBM).
- Alaba jeannettae* BARTSCH, 1910. (5, 6), among rocks and sand (B, SBM).
- \* *Alaba supralirata* CARPENTER, 1857. (5), in sand siftings; Mazatlan, Mexico (B).
- 219 *Cerithidea albonodosa* CARPENTER, in GOULD & CARPENTER, 1857. Common (8), midtide in brackish water (D, M).
- 220 *Cerithidea mazatlanica* CARPENTER, 1857. Common (1, 2, 4, 6), high tide line among rocks (B, D, P).
- 221 *Cerithidea montagnei* (ORBIGNY, 1837). Uncommon (2, 4), intertidal on mangrove roots (D, P).
- 224\* *Rhinocoryne humboldti* (VALENCIENNES 1832). Common (4), in mud in estero; dredged 15 fms.; El Salvador (probably fossil) (B, D, P).
- 227 *Hipponix pilosus* (DESHAYES, 1832). Uncommon (2, 5, 6), intertidal on rocks; common dredged 50-100 fms. on sand, shell, and rock bottom (B, D, K, M, P, S, SBM).
- 229 *Hipponix serratus* CARPENTER, 1857. Uncommon (2, 5, 6), on rocks at low tide (B, M, P, S).
- Thyca callista* BERRY, 1959. Rare (2), parasitic on the asteroid *Phataria unifascialis* GRAY; type locality (B).
- \* *Fossarus megasoma* (C. B. ADAMS, 1852). (6), diving 6-12 m; Panama (M).
- 230 *Vanikoro aperta* (CARPENTER, 1864). Rare (3, 6), dredged 17 fms. on rock and broken shell bottom; diving 6-12 m (D, M, P).
- 232 *Calyptraea conica* BRODERIP, 1834. Common (2, 3, 4, 5, 6), dredged 10-100 fms. on dead shells (D, K, P, S, SBM).
- 233 *Calyptraea mamillaris* BRODERIP, 1834. Common (2, 4, 6), intertidal on dead shells; dredged 45 fms. on sand and rubble bottom (K, P).
- 234 *Calyptraea subreflexa* (CARPENTER, 1857). Uncommon (6), dredged 40 fms. on rock bottom (D).
- 237 *Cheilea cepacea* (BRODERIP, 1834). Rare (1, 3, 4, 6), on dead shells at low tide; uncommon dredged

- 10-17 fms. on rock and broken shell bottom; diving 6-12 m (M, P, SBM).
- 238 *Cheilea corrugata* (BRODERIP, 1834). Rare (6), diving 6-12 m around rocks (B).  
*Capulus sericeus* BURCH & BURCH, 1961. Dredged (6) by BURCH on *Pecten sericeus*; type locality.
- 239 *Crepidula aculeata* (GMELIN, 1791). Uncommon (3, 6), dredged 17-100 fms. on rock bottom (K, P, S, SBM).
- 240 *Crepidula arenata* (BRODERIP, 1834). Common (2, 3, 5), intertidal on shells; dredged 7-45 fms. on shells (D, K, P, SBM).
- 241 *Crepidula excavata* (BRODERIP, 1834). Uncommon (1, 2, 3, 4), intertidal on *Polinices*; dredged 10-17 fms. on rock and gravel bottom (P).
- 242 *Crepidula incurva* (BRODERIP, 1834). Common (4, 5, 6), attached to shells (B, K, M, S).
- 245 *Crepidula onyx* SOWERBY, 1824. Common (4, 5, 6, 9), intertidal on dead shells; dredged 15-40 fms. on rock and broken shell bottom (D, K, M, SBM).
- 247\* *Crepidula rostrata* C. B. ADAMS, 1852. Rare (3, 6), dredged 7-60 fms. on rock and shell bottom; Panama (D, K).
- 248 *Crepidula striolata* MENKE, 1851. Common (3, 4, 5, 6, 9), intertidal under rocks and inside dead shells; dredged 17 fms. in dead shells and mouths of live *Conus* (B, D, K, M, P, S).
- 249 *Crepidula uncata* MENKE, 1847. Rare (6), attached to shells (SBM).
- 250 *Crucibulum lignarium* (BRODERIP, 1834). Uncommon (2, 8, 9), intertidal under rocks (B, D, P).
- 251\* *Crucibulum personatum* KEEN, 1958. (4), on dead shells; Acapulco, Mexico (D).
- 252 *Crucibulum scutellatum* (WOOD, 1828). Common (1, 2, 3, 4, 5, 6, 7, 8, 9), intertidal on rocks; dredged 10-100 fms. on rock and shell bottom (B, D, K, M, P, S, SBM).
- 253a\* *Crucibulum concameratum* REEVE, 1859. Uncommon (1, 6), dredged 10-45 fms. on rock and gravel bottom; Acapulco, Mexico (B, P).
- 254 *Crucibulum spinosum* (SOWERBY, 1824). Common (1, 2, 3, 4, 6, 7, 8), intertidal on rocks; dredged 10-40 fms. on rock bottom (B, D, K, M, P, S, SBM).
- 255 *Crucibulum umbrella* (DESHAYES, 1830). Uncommon (2, 6), intertidal under rocks (B, D, M, P).
- \* *Crucibulum castellum* BERRY, 1963. Rare (4), dredged 10-15 fms. on rock and broken shell bottom; Acapulco, Mexico (P).
- 256\* *Xenophora robusta* VERRILL, 1870. Uncommon (3, 4, 6), dredged 10-25 fms. on sand and gravel bottom; La Paz (B, D, P).
- 258 *Natica chemnitzii* PFEIFFER, 1840. Common (2, 3, 4, 6), intertidal on sand flats; dredged 10-17 fms. on silt and mud bottom (B, D, M, P, SBM).
- 261 *Natica idiopoma* PILSBRY & LOWE, 1932. Uncommon (3), dredged 17 fms. on rock and gravel bottom (P).
- 263 *Natica broderipiana* RÉCLUZ, 1844. Common (3, 5, 6), dredged 15-60 fms. on rock and gravel bottom (B, D, M, P, S, SBM).
- 264 *Natica elenae* RÉCLUZ, 1844. (6), dredged 20-40 fms. (B).
- 266 *Polinices bifasciatus* (GRAY, 1834). Common (2, 3, 4), intertidal on sand flats; dredged 7-20 fms. on sand bottom (D, M, P, SBM).
- 267 *Polinices caprae* (PHILIPPI, 1852). (6), dead specimen from sand bottom near rocky rubble at 10 m (SHASKY, 1964).
- 272 *Polinices uber* (VALENCIENNES, 1832). Common (2, 3, 4, 5, 6, 8), intertidal on sand flats; dredged 10-20 fms. on rock and broken shell bottom (B, D, M, P, SBM).
- 272a *Polinices panamensis* (RÉCLUZ, 1844). (4), in estero (B).
- 274 *Polinices reclusianus* (DESHAYES, 1839). Uncommon (2), on sand beach at low tide (M, SBM).
- \* *Sinum grayi* (DESHAYES, 1843). (6), dredged 20-40 fms.; Chile-Peru (B).
- 280\* *Lamellaria inflata* (C. B. ADAMS, 1852). Uncommon (2, 3, 5, 6), intertidal under rocks; dredged 17 fms. on rock bottom; Panama (D, P, SBM).
- 281 *Cypraea albuginosa* GRAY, 1825. Rare (3, 5, 6), intertidal under rocks; dredged 17 fms. on rock bottom (K, M, P, S).
- 282\* *Cypraea isabellamexicana* STEARNS, 1893. (1), intertidal under rocks; La Paz, Lower California (P).
- 283 *Cypraea cervinetta* KIENER, 1843. Uncommon (2, 6, 9), intertidal under rocks and below tide line to approximately 10 feet (D, P).
- 284 *Cypraea arabicula* LAMARCK, 1811. Uncommon (2, 4, 5, 6), intertidal under rocks (D, K, M, P, SBM).
- 287 *Cypraea annettae* DALL, 1909. Common (1, 2, 3, 4, 5, 6), intertidal under rocks; uncommon dredged 10-20 fms. on rock bottom (D, K, M, P, S, SBM).
- 289 *Erato columbella* MENKE, 1847. Uncommon (2, 3, 4, 5, 6), intertidal under rocks; common dredged 17-60 fms. on rock and gravel bottom (D, M, P, SBM).
- 296 *Trivia californiana* (GRAY, 1828). Uncommon (2, 3, 6), intertidal under rocks; common dredged 17 fms. on rock and gravel bottom (B, D, P, SBM).

- 297 *Trivia radians* (LAMARCK, 1810). Uncommon (2, 3, 6), intertidal under rocks; dredged 17 fms. on rock bottom (B, D, P, SBM).
- 298 *Trivia sanguinea* (SOWERBY, 1832). Rare (3, 6), dredged 17 fms. (D, M, SBM).
- 299 *Trivia solandri* (SOWERBY, 1832). Common (3, 5, 6), intertidal under rocks; uncommon dredged 17 fms. on rock and gravel bottom (B, D, K, M, P, SBM).
- \* *Trivia myrae* CAMPBELL, 1961. Common (1, 3, 4), dredged 10-17 fms. on gravel bottom; Carmen Island, Gulf of California (B, D, P).
- 300\* *Jenneria pustulata* (SOLANDER, 1786). Uncommon (2, 3, 5, 6, 8), intertidal on rocks; dredged 17 fms. on rock bottom; diving 6-12 m; southern part of Gulf of California (D, K, M, P, S, SBM).
- 301 *Cyphoma emarginatum* (SOWERBY, 1830). (6), dredged 60 fms. (dead specimen) (D).
- 303 *Neosimnia avena* (SOWERBY, 1832). Uncommon (4, 5), intertidal on gorgonians (B, P).
- 305 *Neosimnia quaylei* (LOWE, 1935). Common (2, 4, 5, 6), just below low tide, color appears to be consistent with that of gorgonians on which they live (B, D, K, P, S).
- \* *Neosimnia vidleri tyrianthina* BERRY, 1960. Common (2, 3, 4, 5, 6), below low tide on purple gorgonians; dredged 17 fms. on purple gorgonians; Cholla Cove, Sonora, Mexico (D, P).
- 307 *Strombus galeatus* SWAINSON, 1823. Common in summer months (2, 5, 6), in tide pools (B, P, SBM).
- 308 *Strombus gracilior* SOWERBY, 1825. Common (2, 3, 4, 5, 6, 9), intertidal on sand flats; dredged 10-25 fms. on sand bottom (B, D, K, M, P, S, SBM).
- 309 *Strombus granulatus* SWAINSON, 1822. Common (1, 2, 3, 4, 5, 6), intertidal on sand flats; dredged 7-20 fms. on sand bottom (B, D, K, M, P, SBM).
- 311\* *Malea ringens* (SWAINSON, 1822). Uncommon (3), dredged 17 fms. on sand and gravel bottom; Mazatlan, Mexico (P).
- 313\* *Cassis coarctata* SOWERBY, 1825. Rare (3, 5, 6), in tide pools around rocks; diving 6-12 m; La Paz (B, D, K, P).
- 315 *Cassis centiquadrata* (VALENCIENNES, 1832). Uncommon (2, 3, 4, 5, 6), intertidal on sand bars; common as juveniles, dredged 15-20 fms. on sand bottom (B, D, K, P, S, SBM).
- 316 *Morum tuberculosum* (REEVE, 1852, *ex* SOWERBY MS.). Rare (1, 2, 4, 6), as beach shells; dredged 60 fms.; diving 6 m (very rare alive) (D, M, P, SBM).
- 317 *Ficus ventricosa* (SOWERBY, 1825). Uncommon (4, 5, 6), as beach shells; dredged 10-20 fms. (dead specimens) (B, P, SBM).
- 319\* *Cymatium amictum* (REEVE, 1844). (6), dredged 60 fms. on sand and broken shell bottom; Mazatlan, Mexico (B, D).
- 321 *Cymatium wiegmanni* (ANTON, 1839). Rare (6), dredged 60 fms. (B, D).
- 322 *Cymatium parthenopeum* (VON SALIS, 1793). (3), dredged 17 fms. (dead specimen) (B).
- 324 *Cymatium gibbosum* (BRODERIP, 1833). Uncommon (2, 3, 4), intertidal around rocks; dredged 17 fms. on rock bottom (D, M, P).
- 325\* *Distorsio constricta* (BRODERIP, 1833). Uncommon (3, 6), dredged 17-60 fms. on sand and silt bottom; southern part of Gulf of California (P, S).
- 326\* *Distorsio decussata* (VALENCIENNES, 1832). Uncommon (3, 5, 6), dredged 10-15 fms. on sand and silt bottom; southern part of Gulf of California (B, D, SBM).
- 327\* *Bursa caelata* (BRODERIP, 1833). (6), diving 12 m (SHASKY, 1964); Mazatlan, Mexico.
- 330\* *Bursa nana* (BRODERIP & SOWERBY, 1829). (6), dredged 20-40 fms.; Mazatlan, Mexico (B).
- \* *Bursa californica sonorana* BERRY, 1960. (6, 9), as beach shells; dredged 45-90 fms.; Cholla Cove, Sonora, Mexico (B, D, M, P).
- 334\* *Colubraria siphonatus* (REEVE, 1844). Common (1, 2, 3, 4, 5, 6), dredged 10-60 fms. on rock and gravel bottom; Nicaragua (B, D, K, P, S, SBM).
- 335 *Murex elenensis* DALL, 1909. Uncommon (6, 9), in egg masses on beach; dredged 20 fms. (B, D, P).
- 336a *Murex recurvirostris lividus* CARPENTER, 1857. Rare (1, 2, 3, 4, 6), intertidal among rocks; common dredged 15-100 fms. on sand and broken shell bottom (B, D, K, P, S).
- 337 *Pteropurpura centrifuga* (HINDS, 1844). Rare (3, 6), dredged 45-100 fms. on sand and broken shell bottom (B, S).
- 338\* *Hexaplex brassica* (LAMARCK, 1822). (3), dredged 15 fms.; Mazatlan, Mexico (B).
- 339 *Hexaplex erythrostomus* (SWAINSON, 1831). Common (2, 3, 4, 5, 8), intertidal on sand flats; dredged 10-20 fms. on sand bottom (B, D, K, M, P, SBM).
- 342\* *Maxwellia humilis* (BRODERIP, 1833). Rare (3, 4, 5, 6), dredged 10-20 fms. on rock and silt bottom; Nicaragua (B, D, P, SBM).
- 343a *Muricanthus callidinus* BERRY, 1958. (6), diving at 6 m (M).
- 344 *Muricanthus nigrilus* (PHILIPPI, 1845). Common (2, 3, 4, 5, 8), intertidal in sand close to rocks and on mud flats of esteros; uncommon dredged 10-17 fms. (B, D, M, P).
- 345 *Muricanthus oxyacantha* (BRODERIP, 1833). (6), diving 6-12 m (M).

- 346\* *Muricanthus princeps* (BRODERIP, 1833). Common (2), intertidal among rocks; southern part of Gulf of California (D, M, P).
- 348 *Pteropurpura erinaceoides* (VALENCIENNES, 1832). Common (2, 3, 4, 5, 6, 7, 8, 9), intertidal on rocks; dredged 10-45 fms. on rock and gravel bottom (B, D, K, M, P, S, SBM).
- 349\* *Pteropurpura pinniger* (BRODERIP, 1833). Rare (3, 4, 6, 9), as beach shells; dredged 10-20 fms. on rock and gravel bottom; diving 12 m; Panama (B, D, M, P).
- \* *Shaskyus festivus* (HINDS, 1844). Common (7), as juveniles around wharf pilings during December, 1960; Magdalena Bay, Lower California (D).
- 353 *Ocenebra carmen* (LOWE, 1935). Common (1, 3, 6), dredged 10-60 fms. on rock and gravel bottom (B, D, P).
- 358 *Ocenebra parva* (E. A. SMITH, 1877). Common (2, 6), intertidal among rocks; diving 6-12 m (D, M, P, SBM).
- 359\* *Ocenebra peasei* (TRYON, 1880). Rare (3), dredged 17 fms. on rock and gravel bottom; La Paz (D, P).
- 360 *Ocenebra perita* (HINDS, 1844). Rare (3, 4, 5), dredged 10-20 fms. on rock and broken shell bottom (D, P).
- 361\* *Ocenebra radicata* (HINDS, 1844). (3), dredged 15-35 fms.; Mazatlan, Mexico (B).
- 361b\* *Ocenebra hambachi* HERTLEIN, 1958. Rare (3, 4), dredged 5-17 fms. on rock and gravel bottom; Manzanillo, Mexico (B, D, P).
- 364 *Eupleura muriciformis* (BRODERIP, 1833). Common (2, 3, 4, 6, 7, 8), intertidal among rocks; dredged 15-100 fms.; the intertidal form and dredged form are easily separable (D, K, M, P, S, SBM).
- 367 *Muricopsis armatus* (A. ADAMS, 1854). Common (1, 2, 3, 5, 7), intertidal on rocks; dredged 10-20 fms. on rock and gravel bottom (B, D, K, M, P).
- 368\* *Muricopsis pauxillus* (A. ADAMS, 1854). Rare (2, 6), intertidal under rocks; dredged 100 fms.; Mazatlan, Mexico (D, K, SBM).
- 370\* *Vitularia salebrosa* (KING & BRODERIP, 1832). Uncommon (3, 4), just below low tide on base of gorgonians; dredged 15-17 fms. on rock bottom; La Paz (B, M, P).
- 372 *Trophon cerrosensis* DALL, 1891. Rare (6), dredged 45-90 fms. (D).
- Trialatella cunninghamae* BERRY, 1964. Rare (1, 3), dredged 10-17 fms. on rock and gravel bottom; type locality (B, P).
- 379\* *Phyllocoma scalariformis* (BRODERIP, 1833). (1), diving 10 m, under rocks (SHASKY & CAMPBELL, 1964); Central America to the Galápagos Islands.
- 383 *Typhis lowei* PILSBRY, 1931. Rare (1, 3), dredged 10-20 fms. on rock and gravel bottom (B, D, P).
- 385\* *Typhis coronatus* BRODERIP, 1833. Common (1, 2, 3, 4, 5, 6), dredged 10-20 fms. on rock and silt bottom; southern part of Gulf of California (B, D, K, M, P, S, SBM).
- Typhis grandis* A. ADAMS, 1855. Uncommon (1, 3, 4), dredged 10-20 fms. on rock and silt bottom; diving 6-12 m (B, D, M, P).
- 387 *Coralliophila costata* (BLAINVILLE, 1832). (6), diving 6-12 m (M).
- 388 *Coralliophila hindsii* (CARPENTER, 1857). Uncommon (1, 4), dredged 15 fms. on broken shell and gravel bottom (P).
- \* *Coralliophila incompta* BERRY, 1960. Uncommon (1, 3, 4, 6), dredged 10-45 fms. on rock and gravel bottom; Angel de la Guarda Island, Gulf of California (B, K, P).
- 396 *Thais speciosa* (VALENCIENNES, 1832). Common (2, 3, 4, 6), intertidal on rocks (D, K, M, P, S, SBM).
- 397\* *Thais triangularis* (BLAINVILLE, 1832). Uncommon (2, 6), intertidal on rocks; Cape San Lucas (B, D, K, M, P, S, SBM).
- 398 *Thais biserialis* (BLAINVILLE, 1832). Common (2, 3, 6), intertidal on rocks (B, D, K, M, P, S, SBM).
- 401 *Thais kiosquiformis* (DUCLOS, 1832). Uncommon (4), feeding on oysters on mangrove roots (P).
- 404 *Acanthina angelica* I. OLDROYD, 1918. Common (6), intertidal on rocks (D, P, S, SBM).
- 408\* *Acanthina muricata* (BRODERIP, 1832). (6), dredged 20-40 fms.; southern Mexico (B).
- 409 *Acanthina tuberculata* (SOWERBY, 1835). Common (2, 4, 6), intertidal on rocks (B, D, M, P, S, SBM).
- 411 *Morula ferruginosa* (REEVE, 1846). Common (2, 4, 6), intertidal under rocks (B, K, M, P, SBM).
- 412 *Morula lugubris* (C. B. ADAMS, 1852). Uncommon (6), intertidal under rocks (M, SBM).
- 414 *Purpura patula pansa* GOULD, 1853 (?1852). Common (2, 6), intertidal on rocks (D, P, S).
- Decipifus gracilis* McLEAN, 1959. Rare (5, 6), under rocks at low tide; type locality (M, P, SBM).
- 424 *Anachis coronata* (SOWERBY, 1832). Common (2, 3, 4, 5, 6, 8), intertidal under rocks; dredged 10-40 fms. (D, K, M, P, SBM).
- 437 *Anachis hilli* PILSBRY & LOWE, 1932. Uncommon (2, 3, 4, 6), intertidal under rocks; dredged 17 fms. on rock and gravel bottom (D, M, P, SBM).
- 439\* *Anachis incerta* (STEARNS, 1892). Rare (1, 5, 6), diving 6 m, under rocks; Tres Marias Islands and

- Mazatlan, Mexico (M, SBM).
- 442 *Anachis milium* (DALL, 1916). (5), low tide in estero (S).
- 444 *Anachis nigricans* (SOWERBY, 1844). (6), intertidal under rocks (D).
- 448 *Anachis pygmaea* (SOWERBY, 1832). Common (2, 4, 5, 6), intertidal under rocks; dredged 5 fms. (B, D, M, P, SBM).
- 450\* *Anachis ritteri* HERTLEIN & STRONG, 1951. Uncommon (2), intertidal under rocks; Gulf of Tehuantepec (P).
- 461\* *Anachis tessellata* (C. B. ADAMS, 1852). Uncommon (2), intertidal under rocks; Guatemala (SBM).
- 462\* *Anachis tincta* CARPENTER, 1864. Rare (1), intertidal under rocks; southern part of Gulf of California (SBM).
- 463 *Anachis treva* BAKER, HANNA & STRONG, 1938. Rare (3), dredged 17 fms. on rock and gravel bottom (P).
- 464 *Anachis varia* (SOWERBY, 1832). Common (2, 3, 4, 6), intertidal under rocks; dredged 10-17 fms. on rock and gravel bottom (B, D, K, M, P, SBM).
- 466 *Anachis vexillum* (REEVE, 1858). Common (2, 4), intertidal under rocks (D, K, M, P).
- 470 *Cosmioconcha palmeri* (DALL, 1913). Uncommon (3, 6), dredged 15-60 fms. (D, K, P, S).
- 472 *Cosmioconcha pergracilis* (DALL, 1913). Uncommon (6), dredged 15-25 fms. (D).
- 477\* *Mitrella delicata* (REEVE, 1859). Rare (2), intertidal under rocks; Manzanillo, Mexico (SBM).
- 478\* *Mitrella dorma* BAKER, HANNA & STRONG, 1938. Uncommon (2, 3, 6), intertidal under rocks; dredged 17-60 fms. on rock and gravel bottom; southern part of Gulf of California (D, P, SBM).
- 480 *Mitrella granti* LOWE, 1935. Uncommon (2, 5, 6, 8), intertidal under rocks (D, SBM).
- 481\* *Mitrella harfordi* STRONG & HERTLEIN, 1937. Uncommon (2), intertidal among rocks; Acapulco, Mexico (P).
- 482 *Mitrella lalage* PILSBRY & LOWE, 1932. Uncommon (2, 3, 4, 5), intertidal among rocks; dredged 10 fms. on sea weed and on rock and gravel bottom (B, D, P).
- 483\* *Mitrella millepunctata* (CARPENTER, 1864). Rare (3, 4, 6), intertidal under rocks; dredged 10 fms. on rock and gravel bottom; southern part of Gulf of California (D, M, P, SBM).
- 484 *Mitrella ocellata* (GMELIN, 1791). Common (2, 3, 4, 5, 6, 9), intertidal under rocks; dredged 17 fms. on rock and gravel bottom (D, K, M, P, SBM).
- 486\* *Mitrella santabarbarensis* (CARPENTER in GOULD & CARPENTER, 1857). Uncommon (2, 3, 4), intertidal under rocks; dredged 10-20 fms. on rock and gravel bottom; southern part of Gulf of California (P).
- Nassarina anitae* CAMPBELL, 1961. Uncommon (3, 4, 5, 6), dredged 10-17 fms. on rock and gravel bottom; type locality (B, D, P).
- 494 *Parametaria dupontii* (KIENER, 1849-1850). Common (2, 3, 4, 6), intertidal on rocks; dredged 20 fms. on rock bottom (B, D, K, M, P, S, SBM).
- 498 *Pyrene haemastoma* (SOWERBY, 1832). Uncommon (1, 3, 4, 5, 6), dredged 5-20 fms. on rock and gravel bottom (B, D, K, M, P, SBM).
- 501\* *Pyrene major* (SOWERBY, 1832). Common (2, 6), intertidal around rocks; southern part of Gulf of California (D, M, P).
- 502 *Pyrene strombiformis* (LAMARCK, 1822). Uncommon (2, 5, 6), intertidal around rocks (K, P, SBM). *Pyrene aureomexicana* HOWARD, 1963. Common (2, 3, 4, 6), intertidal among rocks; uncommon dredged 20-45 fms. on rock bottom (D, K, M, P, SBM).
- 504\* *Strombina bonita* STRONG & HERTLEIN, 1937. Rare (6), dredged 45-90 fms.; southern part of Gulf of California (D).
- 508 *Strombina dorsata* (SOWERBY, 1832). Common (3, 4), dredged 17 fms. on rock and gravel bottom (P).
- 512 *Strombina gibberula* (SOWERBY, 1832). Common (1, 3, 4, 5), dredged 10-20 fms. on rock and gravel bottom (D, P, SBM).
- 513 *Strombina hirundo* (GASKOIN, 1852). Rare (5), dredged 10 fms. on sand bottom (S).
- 515 *Strombina maculosa* (SOWERBY, 1832). Common (2, 3, 4, 5, 6), intertidal on sand bars; dredged 10-20 fms. (B, D, M, P, S, SBM).
- 521 *Strombina sinuata* (SOWERBY, 1874). Rare (4), trapped in 20 fms. (P).
- 523 *Strombina subangularis* LOWE, 1935. Uncommon (3, 6), dredged 17-100 fms. on sand and rubble bottom (D, P).
- 525\* *Strombinoturris crockeri* HERTLEIN & STRONG, 1951. Rare (3, 6), dredged 7-100 fms.; southern part of Gulf of California (D, K).
- 530\* *Bailya anomala* (HINDS, 1844). (6), living specimen from under rock resting on gravel bottom (SHASKY, 1964); Nicaragua to Panama.
- 532\* *Caducifer tabogensis* PILSBRY & LOWE, 1932. Rare (3), dredged 17 fms. on rock and gravel bottom; Panama Bay (P).
- Caducifer bilirata* (REEVE, 1846). Rare (6), diving 2-18 m, taken under rocks (B, D, M).
- 536\* *Cantharus panamicus* (HERTLEIN & STRONG, 1951). Rare (6), dredged 40-100 fms. on sand and rubble bottom; southern part of Gulf of California (B, D, K).
- 539\* *Cantharus sanguinolentus* (DUCLOS, 1833). Un-



- common (2, 4, 6), intertidal on rocks; southern part of Gulf of California (D, M, P, SBM).
- 543 *Solenosteira macrospira* (BERRY, 1957). Common (2, 3, 6, 8), intertidal on sand flats; dredged 7-45 fms. on sand and rubble bottom (B, D, K, M, P, SBM).
- \* *Solenosteira gatesi* BERRY, 1963. (6), dredged 20-40 fms.; Mazatlan, Mexico (B).
- Cantharus shaskyi* BERRY, 1959. Uncommon (6), dredged 45-90 fms. (B, S).
- 548 *Engina jugosa* (C. B. ADAMS, 1852). Common (1, 3, 4, 6), dredged 10-90 fms. on sand and rubble bottom (D, P).
- 550a\* *Engina reevei* TRYON, 1883. Uncommon (2, 3, 4, 6), intertidal among rocks; common dredged 10-17 fms. on sand and rubble bottom; southern part of Gulf of California (D, P, SBM).
- 551\* *Engina solida* (DALL, 1917). Uncommon (1, 2, 3, 6), intertidal under rocks; dredged 10-40 fms. on rock and gravel bottom; La Paz (D, K, M, P, SBM).
- 552\* *Engina tabogaensis* BARTSCH, 1931. (6), dredged 20 fms.; diving 6-12 m; Mazatlan, Mexico (B, M).
- 557\* *Metula amosi* VANATTA, 1913. Uncommon (6), dredged 15-25 fms. on sand and broken shell bottom; Acapulco, Mexico (B, D).
- 559 *Phos articulatus* HINDS, 1844. (3), trapped in 40 fms. (P).
- 561\* *Phos crassus* HINDS, 1843. Uncommon (3, 6), dredged 15-100 fms. on rock and gravel bottom; Mazatlan, Mexico (D, P, S).
- 563 *Phos gaudens* HINDS, 1844. Common (2, 3, 4, 5, 6), dredged 10-60 fms. on rock and gravel bottom (D, K, P, S, SBM).
- 565\* *Phos veraguensis* HINDS, 1843. Common (3, 6), dredged 15-100 fms. on sand and rubble bottom; southern part of Gulf of California (B, D, K, P, S).
- 567 *Melongena patula* (BRODERIP & SOWERBY, 1829). Common (4), intertidal among grass in estero (D, P).
- 571\* *Nassarius corpulentus* (C. B. ADAMS, 1852). (5, 6), dredged 10-90 fms. on sand and gravel bottom; southern part of Gulf of California (K, S).
- 574\* *Nassarius gallegosi* STRONG & HERTLEIN, 1937. Uncommon (4, 5, 6), dredged 10-40 fms.; southern part of Gulf of California (D, K, P, S).
- 577 *Nassarius guaymasensis* (PILSBRY & LOWE, 1932). Common (2, 3, 6), intertidal among rocks; dredged 100 fms. on broken shell bottom (B, D, P).
- 583 *Nassarius pagodus* (REEVE, 1844). Uncommon (2, 3, 4, 5, 6), intertidal among rocks; common dredged 15-100 fms. (B, D, K, P).
- 584\* *Nassarius polistes* (DALL, 1917). (4), trapped 20 fms.; Panama (P).
- 587 *Nassarius versicolor* (C. B. ADAMS, 1852). Common (2, 4, 5, 6, 7, 8), intertidal on mud and sand flats; dredged 6-45 fms. on sand and rubble bottom (D, K, M, SBM).
- 591 *Nassarius iodes* (DALL, 1917). Common (2, 4, 9), intertidal on mud and sand flats (B, D, K, P).
- 592 *Nassarius luteostoma* (BRODERIP & SOWERBY, 1829). Uncommon (2, 4), intertidal among rocks and mud in runnels (D, P).
- 593 *Nassarius moestus* (HINDS, 1844). (4), intertidal around rocks (B).
- 595 *Nassarius tiarula* (KIENER, 1841). Uncommon (2, 4, 6), intertidal on mud and sand flats (B, K, M, P).
- \* *Nassarius howardae* CHACE, 1958. (6), dredged 10-15 fms.; San Felipe, Lower California (SHASKY, 1961).
- 598 *Pleuroploca princeps* SOWERBY, 1825. Uncommon (3, 4, 5), at extreme low tide in sandy bays; dredged 10-20 fms. on sand bottom (B, D, M, P).
- 603\* *Latirus ceratus* (WOOD, 1828). Rare (6), intertidal under rocks; southern part of Gulf of California (P).
- 604\* *Latirus concentricus* (REEVE, 1847). Rare (1, 3, 4), dredged 10-30 fms. on rock and broken shell bottom; Acapulco, Mexico (B, P).
- 605 *Latirus hemphilli* HERTLEIN & STRONG, 1951. Rare (3, 4), dredged 10-20 fms. on rock and gravel bottom (P).
- 610 *Fusinus dupetitthouarsi* (KIENER, 1846). Common (4, 5, 6), intertidal on mud in esteros; dredged 10-60 fms. (B, D, K, M, P, SBM).
- 612 *Fusinus ambustus* (GOULD, 1853). Common (1, 2, 3, 4, 5, 6), intertidal on mud flats; dredged 10-45 fms. (B, D, K, M, P, SBM).
- 616 *Fusinus panamensis* DALL, 1908. Rare (6), dredged 100-125 fms. on broken shell bottom (B, D).
- 617 *Fusinus cinereus* (REEVE, 1847). Common (2, 3, 4, 6, 8), intertidal on rocks; dredged 17 fms. on rock bottom (D, M, P, SBM).
- 619 *Fusinus colpoicus* DALL, 1915. Rare (3, 6), dredged 5-17 fms. (B, K).
- 620 *Oliva incrassata* (SOLANDER, 1786). Common (2, 4), intertidal on sand bars (D, P, SBM).
- 624 *Oliva porphyria* (LINNAEUS, 1758). Uncommon (3, 4), dredged 10-17 fms. on rock and gravel bottom (B, P).
- 625 *Oliva spicata* (RÖDING, 1798). Common (1, 2, 4, 5, 6), intertidal on sand bars; dredged 10-15 fms. on sand bottom (D, M, P, SBM).
- \* *Oliva rejecta* BURCH & BURCH, 1962. Uncommon (4, 9), intertidal on sand bars; La Paz, Lower Cali-

- fornia (D, P).
- 627 *Oliva undatella* LAMARCK, 1810. Uncommon (3), dredged 10-12 fms. on rock and gravel bottom (P).
- 630 *Agaronia testacea* (LAMARCK, 1811). Uncommon (2, 4, 9), intertidal on sand bars (B, D, M, P, S).
- 633\* *Olivella cocosensis* OLSSON, 1956. Uncommon (3), dredged 15 fms. on silt bottom; Nicaragua (P).
- 634 *Olivella dama* (WOOD, 1828, *ex* MAWE MS.). Common (2, 3, 4, 5, 6, 9), intertidal on sand bars; dredged 10-30 fms. (B, D, M, P, S, SBM).
- 634a *Olivella fletcheriae* BERRY, 1958. Common (1, 3, 4, 5), dredged 10-20 fms. on sand and gravel bottom (B, P, S, SBM).
- 639 *Olivella anazora* (DUCLOS, 1835). Uncommon (2, 4), intertidal under rocks; dredged 2-3 fms. on sand bottom (P, SBM).
- 640\* *Olivella volutella* (LAMARCK, 1811). Uncommon (2), intertidal under rocks; Central America (M, P).
- 640a *Olivella* cf. *O. walkeri* BERRY, 1958. Uncommon (3), dredged 10-15 fms. on rock and gravel bottom; type locality (P).
- 645 *Olivella zanoeta* (DUCLOS, 1835). (5), dredged 10-15 fms. on sand bottom (SBM).
- 646 *Mitra solitaria* C. B. ADAMS, 1858. Rare (2, 3, 6), intertidal under rocks; dredged 10-30 fms. on rock and gravel bottom (M, P, SBM).
- 647 *Mitra lens* WOOD, 1828. Uncommon (2, 4, 6), in tide pools among rocks (D, M, P, SBM).
- 648\* *Mitra lignaria* REEVE, 1844. (6), diving 10 m, taken in mud under rocks (SHASKY & CAMPBELL, 1964); Mazatlan, Mexico.
- 653\* *Mitra crenata* BRODERIP, 1836. Common (1, 3, 4, 5, 6), dredged 10-30 fms. on rock and gravel bottom; diving 6-12 m; Ecuador (B, M, P, SBM).
- 654 *Mitra dolorosa* DALL, 1903. (Some intergrading with *M. tristis* BRODERIP.) (5), intertidal among rocks (B).
- 655 *Mitra mexicana* DALL, 1919. (6), dredged 20-40 fms. (B).
- 656 *Mitra tristis* BRODERIP, 1836. Common (2, 3, 5, 6), intertidal among rocks (B, D, P, SBM).
- 657\* *Mitra zaca* (STRONG, HANNA & HERTLEIN, 1933). Rare (3, 6), dredged 17 fms. on rock and gravel bottom; diving 6-12 m; southern part of Gulf of California (B, M, P).
- 659\* *Mitra erythrogramma* TOMLIN, 1931. Common (1, 3, 4, 5, 6), dredged 10-60 fms. on silt bottom; Nicaragua (B, D, M, P, SBM).
- 660\* *Mitra gigantea* REEVE, 1844, *ex* SWAINSON MS. Rare (4), trapped in 20 fms.; Panama (P).
- 661 *Mitra hindsii* REEVE, 1844. Uncommon (3, 4, 5, 6), dredged 10-40 fms.; diving 6-12 m (B, D, M, P, SBM).
- \* *Mitra calodinota* BERRY, 1960. Uncommon (3, 4, 6), dredged 10-25 fms. on rock and gravel bottom; Gulf of Nicoya, Costa Rica (B, D, P).
- Mitra directa* BERRY, 1960. (6), dredged in 20 fms. by U. S. S. *Albatross*; type locality (B).
- \* *Mitra inca* ORBIGNY, 1841. Rare (1), dredged 10 fms. on rock and gravel bottom; Peru (P).
- \* *Mitra lindsayi* BERRY, 1960. Common (1, 3, 4, 6), dredged 10-20 fms. on rock and broken shell bottom; Puerto Peñasco, Sonora, Mexico (B, P).
- Mitra malleti* PETIT, 1852. Rare (1, 3, 4, 6), dredged 10-20 fms. on sand and gravel bottom (B, P).
- Mitra sphoni* SHASKY & CAMPBELL, 1964. (1, 3), dredged 10-17 fms. on gravel bottom; type locality (P).
- 663 *Harpa crenata* SWAINSON, 1822. Rare (3, 4, 6), dredged 10-20 fms. on rock and gravel bottom (B, P).
- 664\* *Vasum caestus* (BRODERIP, 1833). Uncommon (3, 4), dredged 10-30 fms. on rock bottom; La Paz (P).
- 666 *Lyria cumingii* (BRODERIP, 1832). Uncommon (2, 3, 4, 5, 6), intertidal among rocks and sand; dredged 5-30 fms.; diving 3-6 m (B, D, K, M, P, S, SBM).
- 669 *Volvarina taeniolata* (MÖRCH, 1860). Common (1, 2, 3, 4, 5, 6), intertidal under rocks; dredged 10-30 fms. on rock and gravel bottom (B, D, K, P, SBM).
- \* *Cystiscus margaritula* (CARPENTER, 1857). (3, 5), dredged 7-10 fms. on sand and gravel bottom; Mazatlan, Mexico (B, K).
- \* *Cystiscus minor* (C. B. ADAMS, 1852). (5), among rocks and sand; Panama (B).
- \* *Cystiscus polita* CARPENTER, 1857. (3), dredged 5 fms. on sand bottom; Mazatlan, Mexico (D).
- 683\* *Cancellaria decussata* SOWERBY, 1832. Rare (3), dredged 17 fms. on rock and gravel bottom; southern part of Gulf of California (P).
- 684 *Cancellaria gemmulata* SOWERBY, 1832. Rare (3, 5), dredged 10-15 fms. on rock and gravel bottom (B, P, SBM).
- 685 *Cancellaria obesa* SOWERBY, 1832. Uncommon (1, 3, 4), intertidal on sand bars; dredged 10-20 fms. on rock and gravel bottom (D, P).
- 686 *Cancellaria urceolata* HINDS, 1843. Uncommon (3, 5), dredged 10-15 fms. on rock and gravel bottom (D, P, SBM).
- 690 *Cancellaria pulchra* SOWERBY, 1832. Rare (1, 4), dredged 15 fms. on silt bottom; trapped in 20 fms.



- (B, P).
- 693 *Cancellaria cassidiformis* SOWERBY, 1832. Common (2, 3, 4, 5, 6), intertidal on sand beach; dredged 10-30 fms. on silt bottom (B, D, P, S, SBM).
- 696 *Cancellaria indentata* SOWERBY, 1832. Common (3, 4, 5), dredged 10-17 fms. on silt and sand bottom (B, P, SBM).
- 699\* *Cancellaria clavatula* SOWERBY, 1832. Rare (3, 7), dredged 10-20 fms. on silt and broken shell bottom; Mazatlan, Mexico (B, D).
- \* *Cancellaria corrugata* HINDS, 1843. Rare (3), dredged 17 fms. on rock and gravel bottom; Ecuador (B, P).
- \* *Cancellaria strongi* SHASKY, 1961. Uncommon (6), dredged 45-90 fms. on sand and shell bottom; Point Arena, Lower California (D).
- 707\* *Trigonostoma bullatum* (SOWERBY, 1832). Rare (3, 6), dredged 17-100 fms. on rock, sand, and broken shell bottoms; Acapulco, Mexico (B, D, P, S).
- 710 *Trigonostoma goniosoma* (SOWERBY, 1832). Uncommon (3, 6), dredged 20 fms. on rock and sand bottom; diving 3-6 m (M, P).
- Trigonostoma campbelli* SHASKY, 1961. Uncommon (3, 4, 5, 6), dredged 5-20 fms. on silt, sand, and gravel bottoms; type locality (B, D, M, P, SBM).
- 716\* *Daphnella allemani* (BARTSCH, 1931). Rare (3, 4), dredged 17 fms. on rock and gravel bottom; Panama (B, P).
- 717 *Daphnella bartschi* DALL, 1919. Rare (3, 5, 6), intertidal under rocks; dredged 17 fms. on rock and gravel bottom (P, SBM).
- 720\* *Daphnella mazatlanica* PILSBRY & LOWE, 1932. Rare (6), under rocks at low tide; southern part of Gulf of California (SBM).
- 721\* *Daphnella panamica* PILSBRY & LOWE, 1932. Uncommon (1, 3), dredged 10-17 fms. on rock and gravel bottom; Nicaragua (P).
- Daphnella crebriforma* (SHASKY & CAMPBELL, 1964). Common (1, 3, 4, 5), dredged 10-20 fms. on silt, sand, and rock bottoms; type locality (D, P, SBM).
- 724\* *Ancistrosyrinx cedonulli* (REEVE, 1843). Common (6), dredged 20-125 fms.; Mazatlan, Mexico (D, S, SBM).
- 726 *Knefastia funiculata* (KIENER, 1839-40, *ex* VALENCIENNES MS.). Uncommon (2, 3, 4, 5, 6), intertidal under rocks; dredged 10-25 fms. on rock bottom; diving 6-12 m (B, D, K, M, P, S, SBM).
- 727 *Knefastia olivacea* (SOWERBY, 1833). (6), among rocks at low tide (SBM).
- 728 *Knefastia tuberculifera* (BRODERIP & SOWERBY, 1829). Common (3, 4, 5, 6), dredged 10-100 fms. (B, D, K, P, S).
- 728a *Knefastia walkeri* BERRY, 1958. (6), dredged 20-40 fms. (B).
- 733 *Clavus hecuba* (DALL, 1919). Uncommon (3, 4, 5), dredged 10-20 fms. on rock and gravel bottom (D, P, S, SBM).
- 736\* *Clavus melea* (DALL, 1919). Uncommon (2, 3, 4, 5), dredged 10-20 fms. on rock and gravel bottom; Panama (D, K, P, SBM).
- 741 *Clavus roseolus* (HERTLEIN & STRONG, 1955). Common (3, 4, 5, 6), dredged 10-40 fms. on silt, sand, and rock bottoms (D, K, M, P, S, SBM).
- 742\* *Clavus strohbeeni* (HERTLEIN & STRONG, 1951). Uncommon (3), dredged 17 fms. on rock and gravel bottom; Cape San Lucas, Lower California (P).
- 743\* *Clavus walteri* (M. SMITH, 1946). Common (1, 3, 4), dredged 10-30 fms. on silt bottom; Panama (D, K, M, P, S).
- 744\* *Clavus abdera* (DALL, 1919). Uncommon (3, 4), dredged 10-20 fms. on rock and gravel bottom; Panama (B, D, K, P).
- 745\* *Clavus acapulcanus* (LOWE, 1935). Common (1, 3, 4, 5, 6), dredged 10-20 fms. on sand and gravel bottom; Acapulco, Mexico (D, K, P, S).
- 746 *Clavus aeginus* (DALL, 1919). Uncommon (3), dredged 17 fms. on rock and gravel bottom (D, P).
- 748 *Clavus aerope* (DALL, 1919). Uncommon (3, 6), dredged 17-100 fms. on rock and gravel bottom; diving 6-12 m (D, M, P).
- 750\* *Clavus clavatus* (SOWERBY, 1834). Rare (5), dredged 10-15 fms.; Panama (SBM).
- 751\* *Clavus* cf. *C. craneanus* (HERTLEIN & STRONG, 1951). (5), dredged 10 fms. on sand bottom; Panama (S).
- 752 *Clavus cretatus* (E. A. SMITH, 1888). Rare (3, 4, 5), dredged 15 fms. on rock and gravel bottom; Panama (B, P, S).
- 755\* *Clavus micans* (HINDS, 1843). Rare (3), dredged 17 fms. on sand and gravel bottom; Nicaragua (D).
- 756\* *Clavus pallidus* (SOWERBY, 1834). Uncommon (3), dredged 17 fms. on rock and gravel bottom; Tenacatita Bay (D, P).
- 758 *Clavus pembertoni* LOWE, 1935. Uncommon (3, 6), dredged 17-60 fms. on gravel and broken shell bottom (D, P).
- 759 *Clavus pilsbryi* (BARTSCH, 1950). Uncommon (3, 6), dredged 15-25 fms. on sand and rubble bottom (B, D).
- 760 *Clavus unimaculatus* (SOWERBY, 1834). Rare (6), dredged 40 fms. (P).

- 761 *Clavus alcmene* (DALL, 1919). Rare (3, 4), dredged 15 fms. on rock and gravel bottom (B, K, P).
- 764 *Clavus zacae* (HERTLEIN & STRONG, 1951). Rare (3), dredged 15 fms. on rock and gravel bottom (P).
- 765 *Clathrodrillia callianira* DALL, 1919. Common (1, 3, 4, 5, 6), dredged 10-20 fms. (D, K, P).
- 767\* *Clathrodrillia maura* (SOWERBY, 1834). Rare (1, 3, 4, 6), intertidal among rocks; common dredged 10-40 fms. on rock and gravel bottom; Mazatlan, Mexico (K, P, S, SBM).
- 769 *Clathrodrillia pilsbryi* LOWE, 1935. Common (3, 5), dredged 6-20 fms. on rock and gravel bottom (B, K, P, SBM).
- 770 *Clathrodrillia aenone* DALL, 1919. Common (1, 3, 4, 5, 6), dredged 10-40 fms. (B, D, K, M, P, SBM).
- 771\* *Clathrodrillia adonis* (PILSBRY & LOWE, 1932). Uncommon (3, 6), dredged 17-20 fms. on rock and gravel bottom; Manzanillo, Mexico (D, P).
- 772 *Clathrodrillia alcestis* DALL, 1919. Common (1, 3, 4, 5, 6), dredged 10-100 fms. on sand and rubble bottom (D, K, P, S).
- 773\* *Clathrodrillia dichroa* (PILSBRY & LOWE, 1932). Uncommon (3, 4, 5), dredged 10-30 fms. on sand and rubble bottom; Manzanillo, Mexico (D, K, P, SBM).
- 774\* *Clathrodrillia duplicata* (SOWERBY, 1834). Common (1, 3, 4, 5, 6), dredged 10-25 fms. on sand and rubble bottom; Panama Bay (D, P, SBM).
- 775 *Clathrodrillia haliplexa* DALL, 1919. Common (1, 3, 4), dredged 10-20 fms. on rock and gravel bottom (P).
- 776\* *Clathrodrillia halis* DALL, 1919. Common (1, 3, 4, 5, 6), dredged 10-100 fms. on rubble bottom; Manzanillo, Mexico (B, D, P, SBM).
- 776a *Clathrodrillia halis soror* (PILSBRY & LOWE, 1932). Common (1, 3, 4, 5, 6), dredged 10-20 fms. (D, K, P).
- 777\* *Clathrodrillia jaculum* (PILSBRY & LOWE, 1932). Uncommon (3, 4), dredged 10-20 fms. on rock and gravel bottom; Manzanillo, Mexico (P).
- 778 *Clathrodrillia thestia* DALL, 1919. Rare (3, 4), dredged 10-20 fms. on rock and gravel bottom (P).
- \* *Clathrodrillia bicarinata* SHASKY, 1961. Uncommon (3, 6), dredged 15-90 fms.; Espíritu Santo Island, Gulf of California (D, K).
- 780\* *Crassispira adana* (BARTSCH, 1950). Rare (3), dredged 17 fms. on rock and gravel bottom; Manzanillo, Mexico (P).
- 783\* *Crassispira albovallosa* (CARPENTER, 1857). Rare (3), dredged 17 fms. on rock and broken shell bottom; Mazatlan, Mexico (P).
- 786\* *Crassispira aterrima* (SOWERBY, 1834). Uncommon (2, 6), intertidal under rocks; Mazatlan, Mexico (D, K, P).
- 790\* *Crassispira bacchia* DALL, 1919. Uncommon (1, 2, 3, 5), intertidal under rocks; dredged 17 fms. on rock bottom; La Paz, Lower California (B, D, P).
- 792 *Crassispira bottae* (KIENER, 1839-40, *ex* VALENCIENNES MS). Uncommon (3), dredged 17 fms. on rock bottom; diving 6-12 m (M, P).
- 794\* *Crassispira brujae* HERTLEIN & STRONG, 1951. Rare (3), dredged 17 fms. on rock and broken shell bottom; southern part of Gulf of California (B, P).
- 801\* *Crassispira epicasta* DALL, 1919. Rare (1, 3), dredged 10-17 fms. on rock and gravel bottom; Acapulco, Mexico (P).
- 802\* *Crassispira erebus* PILSBRY & LOWE, 1932. Common (1, 3, 4, 5, 8), intertidal on rocks; dredged 10-20 fms. on rock and gravel bottom; southern Mexico (K, P).
- 803\* *Crassispira ericana* HERTLEIN & STRONG, 1951. Uncommon (3, 5, 6), dredged 10-25 fms. on silt and shell bottom; southern part of Gulf of California (D, K).
- 806\* *Crassispira excentrica* (SOWERBY, 1834). Rare (3, 4), dredged 15-20 fms. on rubble and sand bottom; Acapulco, Mexico (D, P).
- 807\* *Crassispira flavonodosa* PILSBRY & LOWE, 1932. Uncommon (1, 3), dredged 10-17 fms. on rock and broken shell bottom; Nicaragua (P).
- 809\* *Crassispira grandimaculata* (C. B. ADAMS, 1852). Uncommon (3, 4), dredged 10-20 fms. on rock and gravel bottom; Nicaragua (P).
- 811\* *Crassispira hermanita* PILSBRY & LOWE, 1932. Rare (3, 4), dredged 12-17 fms. on rock and gravel bottom; Acapulco, Mexico (P).
- 821 *Crassispira nigerrima* (SOWERBY, 1834). (5, 6), dredged 10-45 fms. on rock and sand bottom (D, K, SBM).
- 822 *Crassispira nymphia* PILSBRY & LOWE, 1932. Common (2, 6), intertidal under rocks; diving 3-6 m (B, D, M, P, SBM).
- 825 *Crassispira pluto* PILSBRY & LOWE, 1932. Common (2, 5, 6, 8), intertidal under rocks; dredged 40 fms.; type locality (B, D, K, M, P, SBM).
- 826\* *Crassispira reigeni* (BARTSCH, 1950). Uncommon (2), intertidal under rocks; Mazatlan, Mexico (P).
- 829\* *Crassispira rustica* (SOWERBY, 1834). Rare (3), dredged 17 fms. on rock and gravel bottom; Nicaragua (P).
- 830\* *Crassispira solitaria* PILSBRY & LOWE, 1932. Rare (1, 3, 4), dredged 17 fms. on rock and gravel bottom; Mazatlan, Mexico (B, P).
- 833 *Crassispira tepocana* DALL, 1919. Rare (2, 3, 6), in-

- tertidal under rocks; dredged 17-25 fms. on rock and gravel bottom (D, K, P).
- 836 *Crassispira turricula* (SOWERBY, 1834). Rare (4), dredged 15 fms. on rock and gravel bottom (P).
- 839 *Crassispira xanti* HERTLEIN & STRONG, 1951. (6), diving 6-12 m (M).  
*Crassispira cortezi* SHASKY & CAMPBELL, 1964. (6), diving 10-15 m; type locality (SHASKY & CAMPBELL, 1964).
- \* *Crassispira kluthi* JORDAN, 1936. Common (2, 3, 4, 5), dredged 7-20 fms. on rock and gravel bottom; diving 3-6 m; Pleistocene, Magdalena Bay, Lower California (B, K, M, P).
- \* *Crassispira* cf. *C. punctatostriata* CARPENTER, 1857. Uncommon (3), dredged 17 fms. on rock and gravel bottom; Panama (D, P).
- 841\* *Hindsiclava andromeda* (DALL, 1919). Uncommon (6), dredged 15-25 fms. on broken shell and silt bottom; La Paz, Lower California (D).
- 843 *Hindsiclava militaris* (REEVE, 1843, ex HINDS MS.). Common (3, 4, 5, 6), dredged 10-40 fms. on sand and silt bottom (K, P, S, SBM).
- 844\* *Syntomodrillia cybele* PILSBRY & LOWE, 1932. Common (1, 3, 4, 6), dredged 10-60 fms. on rock and gravel bottom; Acapulco, Mexico (D, P).
- 846\* *Mangelia bella* (HINDS, 1843). (3), dredged 7-20 fms. on sand and rubble bottom; Nicaragua (D, K).
- 850\* *Mangelia ericea* (HINDS, 1843). Rare (3, 4), dredged 17 fms. on rock and gravel bottom; Panama (D).
- 851 *Mangelia erminiana* (HERTLEIN & STRONG, 1951). Rare (3), dredged 15 fms. on rock and broken shell bottom (B, P).
- \* *Mangelia janira* (DALL, 1919). Under rocks (6); San Diego, California (D).
- 852\* *Mangelia merita* (HINDS, 1843). Uncommon (6), intertidal under rocks; Costa Rica (P).
- 853\* *Diptycophila occata* (HINDS, 1843). Rare (4), dredged 5 fms. on sand bottom; Panama (B).
- 854 *Mangelia rhyssa* DALL, 1919. (2), intertidal under rocks near sand beach (K).
- 858 *Mangelia aethra* (DALL, 1919). Common (1, 3, 4), dredged 10-20 fms. on rock and gravel bottom (B, D, K, P).
- 859 *Mangelia electra* (DALL, 1919). Rare (3), dredged 17 fms. on rock and gravel bottom (P).
- 860\* *Mangelia finitima* (PILSBRY & LOWE, 1932). Rare (1, 3, 4, 6), intertidal under rocks; dredged 15-20 fms. on rock and broken shell bottom; Nicaragua (P).
- 862 *Mangelia melita* (DALL, 1919). Rare (3), dredged 17 fms. on rock and gravel bottom (D, P).
- 863a *Mangelia euryclea* DALL, 1919. Rare (3), dredged 17 fms. on rock and gravel bottom (D, P).
- 866\* *Mangelia subdiaphana* CARPENTER, 1864. (3), dredged 15-20 fms.; Cape San Lucas (D).
- \* *Crockerella pedersenii* HERTLEIN & STRONG, 1951. Rare (3), dredged 17 fms. on rock and gravel bottom; Santa Inez Bay, Gulf of California (P).
- 867\* *Mangelia antiochroa* PILSBRY & LOWE, 1932. (5), dredged 10 fms. on sand bottom; Panama (S).
- 868\* *Mangelia antipyrus* PILSBRY & LOWE, 1932. Rare (3, 4), dredged 10-17 fms. on rock and broken shell bottom; Acapulco, Mexico (D, P).
- 869\* *Mangelia cymatias* PILSBRY & LOWE, 1932. Rare (1, 2, 3, 4), intertidal under rocks; dredged 10 fms. on rock and gravel bottom; Acapulco, Mexico (K, P).
- \* *Mangelia melanosticta* PILSBRY & LOWE, 1932. Rare (3), dredged 17 fms. on rock and broken shell bottom; Nicaragua (P).
- \* *Mangelia roperi* DALL, 1919. Rare (3), dredged 15-17 fms. on rock and broken shell bottom; Pacific coast of Lower California (P).
- 871\* *Clathurella affinis* DALL, 1871. Rare (1, 3, 6), intertidal under rocks; dredged 17 fms. on rock and gravel bottom; diving 6 m; Cape San Lucas (B, D, P).
- 874\* *Clathurella rava* (HINDS, 1843). Rare (1, 3, 4), dredged 10-20 fms. on rock and gravel bottom; Nicaragua (D, P).
- 875\* *Clathurella rigida* (HINDS, 1843). Rare (1, 3), dredged 17-30 fms. on rock and gravel bottom; Panama (P).
- 879 *Clathurella partefilosa* (DALL, 1919). Rare (3, 6), dredged 15-60 fms. on rock and gravel bottom (B, D, P).
- 881\* *Clathurella acapulcana* (PILSBRY & LOWE, 1932). Rare (3, 6), dredged 15-25 fms.; Acapulco, Mexico (D, P).
- 883 *Clathurella adria* (DALL, 1919). Uncommon (1, 2, 3, 4, 5), dredged 5-20 fms. on sand and gravel bottom (D, K, P).
- \* *Clathurella fraternalis* (DALL, 1919). Rare (1, 3, 4), dredged 10-17 fms. on rock and gravel bottom; Cape San Lucas (P).
- \* *Clathurella nana* (DALL, 1919). Rare (3), dredged 17 fms. on rock and gravel bottom; La Paz, Gulf of California (P).
- 884\* *Clathurella armstrongi* (HERTLEIN & STRONG, 1955). Rare (3, 6), dredged 17-60 fms. on rock and gravel bottom; Panama (D, P).
- \* *Clathurella trichoides* (DALL, 1919). (6), diving 6-12 m; Panama Bay (M).
- \* *Notocytharella penelope* (DALL, 1919). Rare (3),

- dredged 10 fms. on sand bottom; Agua Verde Bay (D).
- \* *Notocytharella taeniornata* PILSBRY & LOWE, 1932. Rare (3), dredged 17 fms.; Nicaragua (D).
- 888\* *Notocytharella ephaedra* (DALL, 1919). Uncommon (3, 4), dredged 10-17 fms. on rock and gravel bottom; Panama (P).
- 889\* *Notocytharella hastula* (PILSBRY & LOWE, 1932). Rare (5), dredged 10-15 fms. on sand and gravel bottom; Nicaragua (SBM).
- 892\* *Tenaturris burchi* (HERTLEIN & STRONG, 1951). Uncommon (3, 4, 6), dredged 17 fms. on rock and gravel bottom; southern part of Gulf of California (D, P).
- 893\* *Tenaturris carissima* (PILSBRY & LOWE, 1932). Rare (3), dredged 17 fms. on rock and gravel bottom; Mazatlan, Mexico (D, P).
- 894\* *Tenaturris nereis* (PILSBRY & LOWE, 1932). Uncommon (3, 6), intertidal under rocks; rare dredged 17 fms. on rock and gravel bottom; diving 6-12 m; Nicaragua (D, M, P, SBM).
- 898\* *Turricula hexagona* (SOWERBY, 1834). Rare (3, 6), dredged 17-40 fms. on rock and gravel bottom; El Salvador (K, P).
- 899\* *Tiariturris libya* (DALL, 1919). (6), dredged 20-40 fms.; Cape San Lucas (B).
- 901 *Turricula armilda* (DALL, 1908). Uncommon (6), dredged 45-125 fms. (D, S, SBM).
- 907\* *Turricula panthea* DALL, 1919. (5), dredged 10-15 fms. on sand and gravel bottom; Panama Bay (SBM).
- 908 *Hormospira maculosa* (SOWERBY, 1834). Common (1, 3, 6), intertidal on muddy, rocky reefs; uncommon dredged 40 fms. (B, D, K).
- 909 *Pleuroliria artia* BERRY, 1957. Uncommon (1, 3, 5, 6), dredged 10-100 fms. on rock and gravel bottom (D, K, P, S).
- 910 *Pleuroliria nobilis* (HINDS, 1843). Common (4, 6), dredged 15-100 fms. on sand and broken shell bottom (B, D, K, P, S).
- 911 *Pleuroliria oxytropis* (SOWERBY, 1834). (1, 3, 5, 6), dredged 10-100 fms. (K, P, S, SBM).
- 911a *Pleuroliria oxytropis albicarinata* (SOWERBY, 1870). Common (1, 2, 3, 4, 5, 6), dredged 10-100 fms. on rubble bottom (D, K, P, S).
- 912\* *Pleuroliria parthenia* BERRY, 1957. Rare (3, 6), dredged 10-100 fms. on sand and rubble bottom; Costa Rica (D, K).
- 913 *Pleuroliria picta* (REEVE, 1843, ex BECK MS.). Common (2, 3, 4, 5, 6), dredged 10-100 fms. on rubble bottom; diving 3-6 m (B, D, K, M, P, S).
- 915 *Tiariturris spectabilis* BERRY, 1958. (6), dredged 20-40 fms. (B).
- 917 *Conus brunneus* WOOD, 1828. Common (2, 3, 5, 6), intertidal among rocks; diving 6-12 m (B, D, M, P, S, SBM).
- 920 *Conus gladiator* BRODERIP, 1833. Common (2, 3, 6), intertidal under rocks; uncommon dredged 17 fms. on rock bottom; diving 6-12 m (B, D, K, M, P).
- 921 *Conus nux* BRODERIP, 1833. Common (2, 4, 5, 6), intertidal on rocky ledges; dredged 10 fms. on rock bottom; diving 3-6 m (B, D, K, M, P, S, SBM).
- 922 *Conus princeps* LINNAEUS, 1758. Common (2, 5, 6), intertidal on rocky ledges and in tide pools; diving 6-12 m (B, D, K, M, P, S, SBM).
- 923\* *Conus tiaratus* SOWERBY, 1833, ex BRODERIP MS. Rare (6), taken from surface of large rocks at 5 m (CAMPBELL, 1964); southern Mexico.
- 926 *Conus perplexus* SOWERBY, 1857. (1, 4), on sand beach at low tide; dredged 10-40 fms. (B, D, K, SBM).
- 927 *Conus purpurascens* SOWERBY, 1833, ex BRODERIP MS. Uncommon (2, 6), intertidal among rocks; diving 6-12 m (B, D, K, M, P, S, SBM).
- 928 *Conus tornatus* SOWERBY, 1833, ex BRODERIP MS. Uncommon (1, 3, 5, 6), dredged 10-45 fms. on sand and gravel bottom (B, K, P, S, SBM).
- 929 *Conus vittatus* BRUGUIÈRE, 1792. Rare (6), taken by Dr. Shasky, diving 10 m, under a rock (D).
- 930 *Conus ximenes* GRAY, 1839. Common (2, 3, 4, 5, 6), intertidal on sand bars; dredged 10 fms. on sand bottom; diving 6-12 m (B, D, K, M, P, SBM).
- 931 *Conus mahogani* REEVE, 1843. Uncommon (2, 3, 4), intertidal on sand bars; dredged 10 fms. on sand bottom (B, D, P).
- \* *Conus orion* BRODERIP, 1833 (3), dredged 17 fms. on broken shell and rock bottom; second living specimen reported in the Gulf of California (P).
- 935 *Conus archon* BRODERIP, 1833. Uncommon (3, 5, 6), dredged 5-20 fms. on sand and rubble bottom (B, K).
- 936 *Conus arcuatus* BRODERIP & SOWERBY, 1829. Uncommon (3, 6), dredged 10-100 fms. on rock and gravel bottom (B, D, K, P).
- 938 *Conus fergusonii* SOWERBY, 1873. Uncommon (1, 3, 9), intertidal in sand and around rocks; dredged 10-20 fms. on rock bottom (B, D, P).
- 939 *Conus gradatus* WOOD, 1828. Uncommon (1, 3, 4, 6), dredged 10-40 fms. on sand and rubble bottom (B, P).
- 940 *Conus recurvus* BRODERIP, 1833. (2, 6) dredged 15-25 fms. on sand and rubble bottom (B, D, K).

- 941 *Conus regularis* SOWERBY, 1833. Common (1, 2, 3, 4, 5, 6), intertidal on silt and sand bars; dredged 10-15 fms. on silt and sand bottom (B, D, K, M, P, S, SBM).
- 942 *Conus scalaris* VALENCIENNES, 1832. Common (3, 5, 6), dredged 10-40 fms. on sand and rubble bottom (B, K, P).
- 944 *Conus virgatus* REEVE, 1849. Uncommon (1, 2, 3, 5, 6, 9), intertidal in pools; common dredged 10-25 fms. on rock bottom (B, D, K, M, P, S, SBM).
- 946\* *Terebra lingualis* HINDS, 1844. Uncommon (1, 3, 5, 6), dredged 10-25 fms. on rock and gravel bottom; Mazatlan, Mexico (B, D, K, P, SBM).
- 947\* *Terebra ornata* GRAY, 1834. Rare (1, 3, 6), dredged 10-30 fms. on rock and gravel bottom; diving 6-12 m; Panama (B, M, P).
- 948 *Terebra robusta* HINDS, 1844. Uncommon (3, 4, 5, 6), crawling in sand at low tide, feeding on dead octopus tentacle; dredged 15-25 fms. (D, P).
- 949 *Terebra strigata* SOWERBY, 1825. Rare (2, 4, 6), intertidal among rocks; dredged 10-40 fms. on sand and rock bottom; diving 3-6 m (B, D, M, P).
- 950\* *Terebra iola* PILSBRY & LOWE, 1932. (3, 5), dredged 10-15 fms.; Mazatlan, Mexico (B, K).
- 951\* *Terebra isopleura* PILSBRY & LOWE, 1932. Rare (1, 4), crawling on sand, extreme low tide; dredged 10 fms. on silt bottom; Mazatlan, Mexico (D, P).
- 953\* *Terebra polypenus* PILSBRY & LOWE, 1932. Uncommon (3), dredged 17 fms. on rock and gravel bottom; Mazatlan, Mexico (P).
- 956 *Terebra armillata* HINDS, 1844. Common (3, 4, 5, 9), crawling on sand beach; dredged 5-20 fms. on rock and gravel bottom (D, P).
- 963 *Terebra glauca* HINDS, 1844. Common (3), dredged 10 fms. on silt and sand bottom (P).
- 964 *Terebra hindsii* CARPENTER, 1857. (4), dredged 6 fms. (D).
- 966\* *Terebra ira* PILSBRY & LOWE, 1932. Uncommon (3, 4), dredged 17 fms. on rock and gravel bottom; Mazatlan, Mexico (D, P).
- 968 *Terebra ligyrus* PILSBRY & LOWE, 1932. Uncommon (3, 7, 9), in sand at edge of water; dredged 15 fms. on rock and gravel bottom (B, D, P).
- 970 *Terebra malonei* VANATTA, 1925. (4), dredged 5 fms. (D).
- 971\* *Terebra melia* PILSBRY, 1931. Uncommon (3), dredged 17 fms. on rock and gravel bottom; Panama (P).
- 973 *Terebra panamensis* DALL, 1908. Rare (1, 3), dredged 17 fms. on rock and gravel bottom (P).
- 980 *Terebra variegata* GRAY, 1834. Common (1, 2, 3, 4, 5, 6), intertidal on sand bars; dredged 10-15 fms. on sand and silt bottom (D, P, SBM).
- Terebra churea* CAMPBELL, 1964. Uncommon (1, 3, 4, 5, 6), dredged 10-60 fms. on silt bottom; type locality (D, P, SBM).
- \* *Terebra dushanae* CAMPBELL, 1964. Rare (4), dredged 10 fms. on rock and broken shell bottom; Puertecitos, Gulf of California (P).
- 982 *Bulla gouldiana* PILSBRY, 1895. Common (2, 3, 4, 6), intertidal on silt among rocks; dredged 15 fms. among rocks (B, D, K, P, SBM).
- 983 *Bulla punctulata* A. ADAMS in SOWERBY, 1850. Uncommon (2, 3), intertidal in silt among rocks; dredged 15 fms. among rocks (P).
- 984 *Haminoea angelensis* BAKER & HANNA, 1927. Uncommon (1, 2, 3, 4, 6, 8), intertidal among rocks; dredged 10-17 fms. on gravel bottom (B, K, P, SBM).
- 986 *Haminoea strongi* BAKER & HANNA, 1927. Common (2, 6, 8), intertidal among rocks; dredged 7-20 fms. on sand and gravel bottom (K, SBM).
- 987\* *Alys casta* CARPENTER, 1864. Rare (1, 3), dredged 10-17 fms. on gravel bottom; Cape San Lucas, Gulf of California (P).
- 988 *Alys chimera* BAKER & HANNA, 1927. Rare (1, 3), dredged 10-17 fms. on gravel bottom (P).
- 989 *Alys liriopoe* HERTLEIN & STRONG, 1951. Rare (3), dredged 17 fms. on rock and gravel bottom (P).
- 990 *Acteon traskii* STEARNS, 1897. Uncommon (1, 4, 5), dredged 10-15 fms. on rock and gravel bottom (B, P, SBM).
- 991\* *Acteon panamensis* DALL, 1908. Uncommon (1, 3), dredged 10-17 fms. on gravel bottom; Panama (P).
- 992 *Acteocina angustior* BAKER & HANNA, 1927. Uncommon (1, 2, 3, 5), dredged 7-20 fms. on rock and gravel bottom (D, K, P, S).
- 993\* *Acteocina carinata* (CARPENTER, 1857). (5), in sand siftings; Mazatlan, Mexico (B).
- \* *Cylichnella defuncta* BAKER & HANNA, 1927. Rare (3), dredged 15 fms. on silt bottom; San José Island, Gulf of California (P).
- \* *Berthelinia chloris belvederica* KEEN & A. G. SMITH, 1961. (6); Puerto Ballandra, La Paz, Lower California (SBM).
- 1000 *Pyramidella adamsi* CARPENTER, 1864. Rare (3, 5), intertidal among rock and sand; dredged 5 fms. on sand and rubble bottom (B, D).
- 1001\* *Pyramidella bicolor* MENKE, 1854. (5), dredged 10-15 fms.; southern Mexico (S, SBM).
- 1003 *Pyramidella mazatlanica* DALL & BARTSCH, 1909. (4, 5, 6), dredged 10-45 fms. on sand and rubble bottom (K, P, S).

- 1007\* *Pyramidella panamensis* DALL & BARTSCH, 1909 (3, 5), dredged 10-15 fms. on sand and gravel bottom; Panama Bay (B, SBM).
- 1009\* *Pyramidella* cf. *P. linearum* PILSBRY & LOWE, 1932. (5), dredged 10-15 fms. on sand bottom; Acapulco, Mexico (K).
- \* *Chrysallida reigeni* CARPENTER, 1857. (5), among rock and sand; Mazatlan, Mexico (B).
- \* *Chrysallida telescopium* CARPENTER, 1857. (5), among rock and sand; Mazatlan, Mexico (B).
- \* *Chrysallida vizcainoana* BAKER, HANNA & STRONG, 1928. (5), among rock and sand; Agua Verde Bay (B).
- \* *Salassilla laxa* DALL & BARTSCH, 1909. (5), among rock and sand; Scammon's Lagoon, Lower California (B).
- \* *Odostomia salassia scalariformis* CARPENTER, 1857. (5), in sand siftings; Mazatlan, Mexico (B).
- \* *Odostomia iwidella mendozae* BAKER, HANNA & STRONG, 1928. (5), in sand siftings; Cape San Lucas, Lower California (B).
- \* *Odostomia miralda planicostata* BAKER, HANNA & STRONG, 1928. (5), in sand siftings; Cape San Lucas, Lower California (B).
- \* *Turbonilla muricata* CARPENTER, 1857. (5), among rock and sand; Mazatlan, Mexico (B).
- \* *Turbonilla portoparkerensis* HERTLEIN & STRONG, 1951. (3), dredged 17 fms. on rock and gravel bottom; Costa Rica (D).
- \* *Turbonilla vesperis* PILSBRY & LOWE, 1932. (3), dredged 15-35 fms.; Acapulco, Mexico (B).
- 1011 *Pleurobranchus* cf. *P. digueti* ROCHEBRUNE, 1895. (6), taken by Dr. Shasky, diving 3-10 m (D).
- 1021 *Melampus olivaceus* CARPENTER, 1857. Common (7, 9), intertidal in esteros and among mangrove roots (D, P, S).
- 1023 *Melampus tabogensis* C. B. ADAMS, 1852. Rare (2), intertidal among mangrove roots (P).
- \* *Tylodina fungina* GABB, 1865. Rare (6), at low tide, under rock; San Diego, California (D).
- 1032 *Siphonaria maura* SOWERBY, 1835. Uncommon (2, 4, 5, 6), intertidal on rocks (B, K, M, P, S).
- 1033 *Williamia peltoides* (CARPENTER, 1864). Uncommon (1, 6), dredged 10 fms. on gravel bottom; diving 6-12 m (M, P, SBM).
- 1037 *Onchidella binneyi* (STEARNS, 1893). (6), (SBM).
- 14 *Ischnochiton eucosmius* DALL, 1919. (4), attached to rocks (P).
- 16 *Ischnochiton muscarius* (REEVE, 1847). Common (2), on rocks at extreme low tide (P).
- 23 *Ischnochiton tridentatus* PILSBRY, 1893. Common (2, 4, 6), under rocks at extreme low tide; dredged 17 fms. on rock bottom (B, M, P, SBM).
- 27 *Callistochiton gabbi* PILSBRY, 1893. Common (6), under rocks (B, M, SBM).
- 28 *Callistochiton infortunatus* PILSBRY, 1893. Common (3, 4, 6), under rocks; dredged 10-15 fms. on gravel bottom (B, M, P, SBM).
- 37 *Chaetopleura mixta* (DALL, 1919). Uncommon (3, 6), dredged 17-90 fms. on broken shell bottom; diving 10 m (D, M, P).
- 38 *Chaetopleura euryplax* BERRY, 1945. (6), under rocks (B, M, SBM).
- 42 *Lepidozona subtilis* BERRY, 1956. (7), under rocks; type locality (B, M).
- 44 *Stenoplax limaciformis* (SOWERBY, 1832). Common (2, 4, 5), under rocks (B, D, P, SBM).
- 46 *Stenoplax mariposa* (DALL, 1919). Uncommon (1, 4, 6), under rocks and on ledges (B, M, P, SBM).
- 47 *Stenoplax conspicua sonorana* BERRY, 1956. Common (4, 5, 6), on rocks (B, D, M, SBM).
- 49 *Nuttallina crossota* BERRY, 1956. Rare (6), on rock ledges (B, M, SBM).

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- 5 *Chiton virgulatus* SOWERBY, 1840. (4, 6), attached to rocks (M, P, SBM).

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## A Note on Three Species of Mitridae

(Mollusca: Gastropoda)

BY

WALTER OLIVER CERNOHORSKY

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IN MY PAPER on Fijian Mitridae (1965) I have regarded the two distinct species *Mitra variegata* (GMELIN, 1791) and *M. variegata* REEVE, 1844 as conspecific. Since that account was written, I had the opportunity to examine more material of both species and found that certain sculptural differences, which appear to be of a constant nature, indicate two separate species. In *M. variegata* (GMELIN) the interstices of the spiral ridges on the body whorl are pitted, while *M. variegata* REEVE lacks the pittings. In the former species the earlier whorls and a small area anterior to the body whorl suture are crossed by prominent axial ridges which are pitted in the interstices; in *M. variegata* REEVE the earlier whorls are uniformly granulose. Both species will vary appreciably in colour, but live-collected specimens of *M. variegata* (GMELIN) are generally ornamented with dark brown wavy axial lines on the body whorl, and the immediate area next to the columella and sometimes the edge of the labial lip are tinged with orange.

The radulae of two specimens of *Mitra variegata* (GMELIN) have been examined and were found to be quite distinct from the radula of *M. variegata* REEVE, thus confirming their separate specific status. The radula of the former species belongs to the genus *Swainsonia* H. & A. ADAMS, 1853, and resembles that of *S. fissurata* (LAMARCK, 1811); the rhachidians have 8-10 cusps while

the laterals are equipped with 4 strong cusps. The radula of "*Scabricola variegata*" (GMELIN) from Mauritius, figured by CERNOHORSKY (1966, p. 116, fig. 33) is in actual fact the radula of *Mitra variegata* REEVE, which has been renamed *Mitra suffecta* DAUTZENBERG & BOUGE, 1923.

The genus *Scabricola* SWAINSON, 1840 (type species *Mitra serpentina* LAMARCK, 1811 = *Voluta variegata* GMELIN, 1791) should be deleted and placed in the synonymy of *Swainsonia* H. & A. ADAMS. The species *Mitra suffecta* DAUTZENBERG & BOUGE is the only species of *Swainsonia* with a unicuspid rhachidian and lateral teeth. The formation of the laterals suggests an affinity with the genus *Swainsonia*, and the species should be retained in this genus. The two species have been correctly figured in "Marine shells of the Pacific" (CERNOHORSKY, 1967, in press); figure 251 depicts *Swainsonia suffecta* (DAUTZENBERG & BOUGE), and figure 252 *S. variegata* (GMELIN, 1791).

The authorship of *Mitra edentula*, the type species of the subgenus *Dibaphus* PHILIPPI, 1847, should be credited to SWAINSON, 1823 (p. 378) and not to REEVE, 1844. REEVE obviously overlooked SWAINSON's previous description when referring to SWAINSON's manuscript name "*Conohelix edentula*." SWAINSON's description, although brief, is fitting for the species:

"10. *Mitra edentula*

'Shell cylindrical, striated; aperture longer than the spire; outer lip inflexed; columella without teeth.

'Hab. — Mus. Dubois."

SWAINSON's English description is a verbatim translation of his Latin diagnosis which precedes it.

### ACKNOWLEDGMENT

Mr. D. Heppell, Royal Scottish Museum, Edinburgh, was kind enough to procure a copy of the SWAINSON reference, which is acknowledged with thanks.



### NOTES & NEWS

#### *Mitra prosanguinolenta*

J. CATE, 1966

#### Relegated to Synonymy

BY

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INADVERTENTLY, through an error in interpretation of the Rules of the International Commission on Zoological Nomenclature, I have unnecessarily given a new name, *Mitra prosanguinolenta*, to the species *Mitra sanguinolenta* LAMARCK, 1811 (J. M. CATE, 1966). My error was based on the incorrect assumption that in citing a different species as type figure, LAMARCK had thereby described *Mitra sanguinolenta* in synonymy — a practice ruled invalid by the ICZN in Article 11 (d): "Publication in Synonymy."

According to Dr. A. Myra Keen (*in litt.*), there was evidently meant to be a distinction between the terms "Publication in Synonymy" and "Publication as a Synonym."

Various suggestions as to the correct interpretation of this rule have been offered to me in connection with the

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problem — not all in agreement with one another, but nevertheless unanimous in the conclusion that my selection of a new name for the species was unnecessary. It should have been clear to me that since LAMARCK's holotype exists, no further action was called for.

Although I do not consider myself qualified to discuss the relative merits of the different taxonomic viewpoints on this rather complicated problem, I am grateful to all those who furnished their suggestions, and hereby declare *Mitra prosanguinolenta* J. CATE, 1966 an objective synonym of *Mitra sanguinolenta* LAMARCK, 1811.

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A. M. U.

### Pacific Division

THE TWENTIETH ANNUAL MEETING of the American Malacological Union, Pacific Division, will be held this year at the Conference Grounds of Asilomar State Park, which is located at the ocean's edge on the beautiful Monterey Peninsula. The meeting will convene on June 28<sup>th</sup> and end July 1<sup>st</sup>. Members of the AMU and AMU-PD and anyone interested in the study of malacology are invited to attend and to contribute papers. The Concho-

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## INFORMATION DESK

### *What's the Difference?*

Published in Synonymy - Published as a Synonym

BY

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IT IS UNLIKELY that Jean Cate is the only person who has been nonplussed by the distinction between publication of a name as a synonym and publication in synonymy. Whether or not a scientific name is a synonym may depend upon the taxonomist, for the lumpers may group many forms together that would be separated by the splitter, and a splitter erecting a new taxon might base it on differences too minute to be conceded by his colleagues, and hence he would seem to be publishing a name that from the start is a synonym, though later it might prove useful. On the other hand, the introduction within a formal synonymy of a name that had not previously been validated is something else. It usually happens by the mention of manuscript names. For example:

Captain Thomas Brown in his "Illustrations of the Recent Conchology of Great Britain . . . " 1844 (2<sup>nd</sup> edition), page 100, discussed *Tellina depressa* of GMELIN, 1791. His rather sketchy synonymy is as follows (I omit some irrelevant references):

"*Tellina depressa*, pl. 40, f. 12.

*Tellina squalida*, Montagu, p. 56.

*Bosemptra squalida*, Leach MSS, p. 7."

Actually, the *Tellina squalida* dates not from MONTAGU but from PULTENEY, 1799. Some authors consider both it and *T. depressa* GMELIN, 1791, to be synonyms of *T. incarnata* LINNAEUS, 1758. LEACH's manuscript had been rather freely circulated, but no one else had picked up the generic name *Bosemptra*. Thus, Brown could have been considered to have published it, as LAMARCK did *Thyasira*, another LEACH name.

In the International Code of Zoological Nomenclature, first edition (1961), Article 11 requires that a name first

published in a synonymy, as *Bosemptra* was, must be rejected. However, as this requirement was soon found to jeopardize such names as *Thyasira*, which had gained currency, a modification was made in the second edition of the Code (1963). Such names are to be rejected after 1961, but those that have been accepted by authors are to be accepted with the original date and authorship of their appearance in print. The name *Thyasira* thus continues to be cited as of LAMARCK, 1818, but *Bosemptra*, not having been utilized by anyone prior to 1961, is to be ignored or rejected. This is fortunate, for it might otherwise displace *Laciolina* IREDALE, 1937, a name now being used for several Pacific and Atlantic species of tellens. The same principle holds for the proposal of specific names in synonymy. P. P. CARPENTER, for example, cited several names that he had intended to propose and that he had in manuscript in his provisional catalogue, but when he published his Mazatlan Catalogue, he relegated them to the synonymy of species described in 1852 by C. B. ADAMS; these might have been revived by authors prior to 1961, but few were.

## METHODS & TECHNIQUES

### The Corrosion-Vinyl Acetate Technique as an Aid in the Reconstructon of the Marine Molluscan Alimentary System

BY

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IT IS OFTEN DIFFICULT to get an accurate perspective of the molluscan alimentary system using solely dissection and serial sections as tools for reconstruction. This is especially true for the branching of the digestive diverticula and the orientation of the digestive tract.

Casts have been employed by many workers as a supporting technique for the study of anatomical details of the molluscan alimentary system and its organs. Stomach casts of *Anodonta cclensis* were prepared using plaster by GUTHEIL (1912, p. 447). YONGE (1926, p. 299) employed a concentrated solution of gelatin as a material

for casting the stomach of *Ostrea edulis*. AWATI & RAI (1931, after GALTISOFF, 1964, p. 219) used a mixture of paraffin and resin, which had been colored with carmine, for this purpose on *Ostrea cucullata* (the Bombay oyster). GALTISOFF (1964, p. 219) made latex casts of the alimentary tract of *Crassostrea virginica*. These methods have produced credible models of the gross anatomy of molluscan digestive systems but, due to the viscosity of the casting materials used, none demonstrate the tubules of the digestive diverticula. Vinyl acetate, by virtue of its excellent fluid properties during injection and its durability as a cast material, can produce detailed models of these structures (see Figure 1).

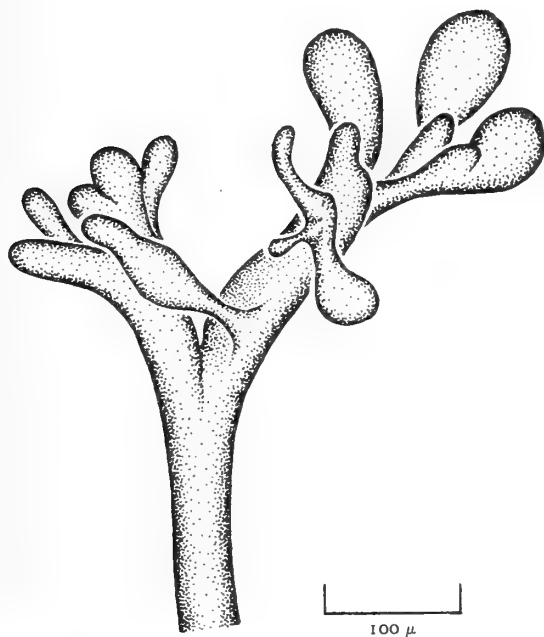


Figure 1

Drawing of a Vinyl Acetate Cast of the Liver Tubules of *Adula (Botula) falcata* (GOULD, 1851) (Filibranchia)

The corrosion-vinyl acetate technique has been used many years for tracing the paths of vertebrate and invertebrate circulatory systems. Using this method, liquid vinyl acetate is injected into blood vessels and, after the plastic has solidified, the tissues are digested away by a

proteinas, leaving a male cast of the injected vessels. The author constructed casts of the alimentary systems of both marine gastropods and lamellibranchs using an application of this technique. The following materials and procedures were found to yield the best results.

Liquid vinyl acetate may be obtained in several colors from biological supply houses. Either acetone or diethyl phthalate serves as a thinner-cleaner. The author used a 1.0 cc B-D Yale Tuberculin syringe and standard Stubbs Gauge 22 needle for the injection of the vinyl acetate. Disposable syringes and needles were tried initially but the action of the pistons was not smooth and the plastic needle sleeves dissolved due to a solvent contained in the vinyl acetate. To prevent the needle from puncturing tissues during its insertion into the mollusk's mouth, the point was smoothed with emery paper.

Before injection with vinyl acetate, the alimentary system should be free of food and feces as their presence creates artifacts in the plastic cast or prevents passage of the liquid acetate during injection. One to three days in filtered sea water will usually clear the alimentary system of most marine mollusks and it is convenient to relax them at the same time. The propylene phenoxetol method of OWEN (1955) is very suitable for the latter purpose.

It is not necessary to dissect a relaxed gastropod to expose its mouth, but pelecypods usually require severing of the adductors, mantle muscles, and part of the mantle fold of one side in order to reveal this opening. The specimen to be injected should be firmly anchored in order to leave both hands of the operator free for the delicate procedure of vinyl acetate injection.

Carefully push the needle a short distance down the pharynx of the relaxed mollusk so that when the plastic is being injected, it does not flow back around the sides of the needle (this is an arbitrary distance differing slightly with different animals). Liquid vinyl acetate will set up quickly after leaving the syringe so that it must be injected at a uniform speed, slow enough not to rupture the walls of the alimentary canal and yet fast enough to prevent it from prematurely solidifying. When the specimen is fully injected, a slight back pressure can be felt on the syringe piston. Any further injection results in ruptured tissues.

After allowing the vinyl acetate to harden for 3 to 6 hours, the injected specimen is placed in a 20% solution of sodium hydroxide in water. The dissolving of the tissues surrounding the plastic cast takes from 1 to 5 days, depending on the size of the mollusk. The casts are usually delicate and should be stored in glass vials filled with distilled water.

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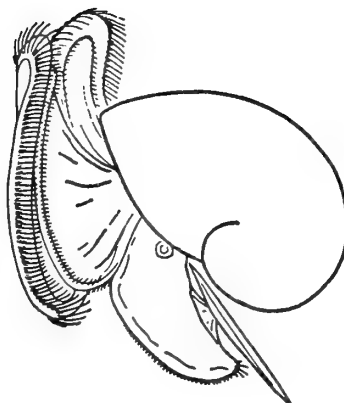
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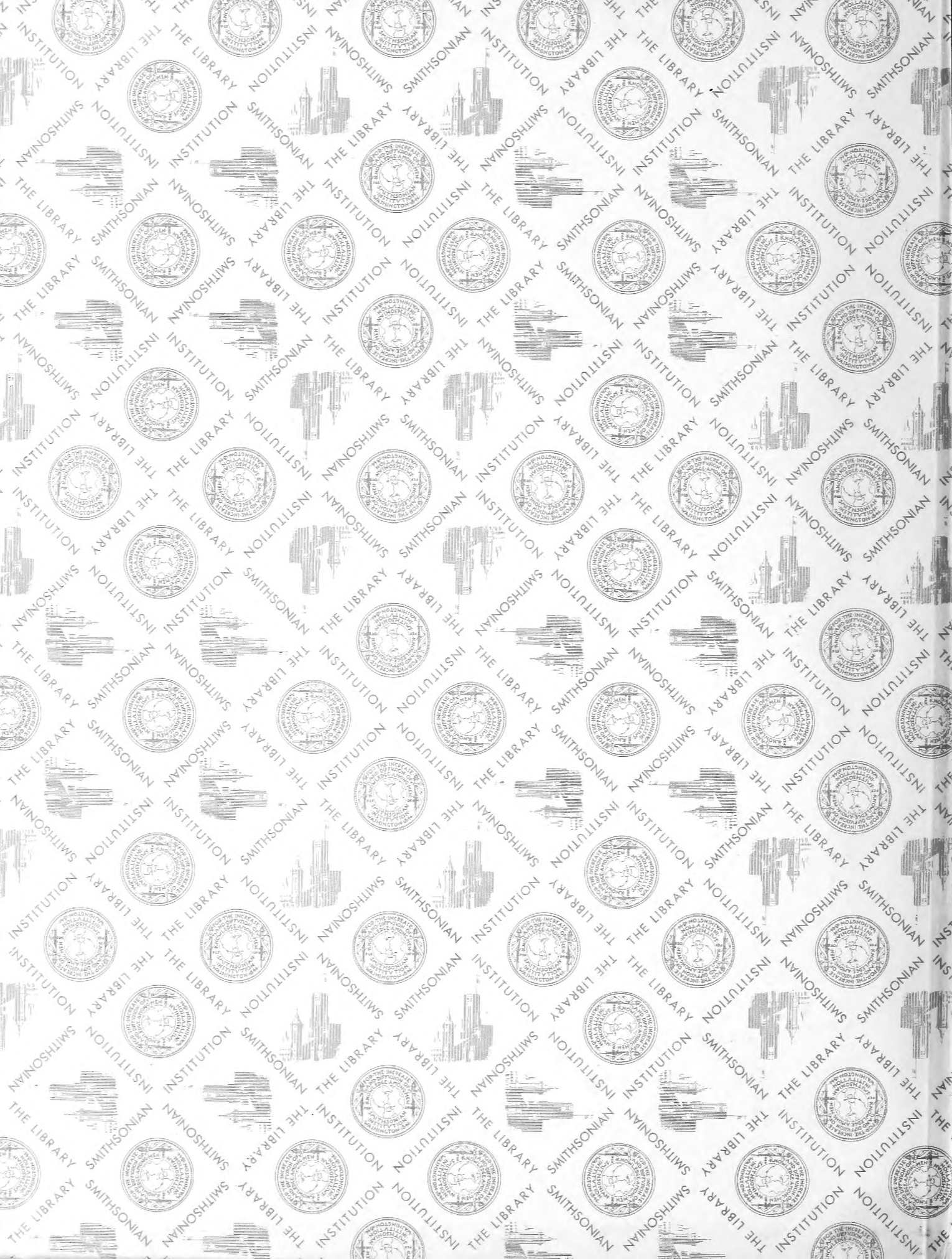
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